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Academy News

Cover page photograph : Damagedweed plant *Parthenium hysterophorus* (See page 112)

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EDITORS' PAGE

Science and Technology (S & T) in India is still groping in the dark to find its rightful place in the societal development. Many times Indian S & T ship of researchers seems to loose its bearing completely. Where to go and for what? We often lament that the gap between S & T academia and Indian Industry is too wide and any sign of its bridging in the near future also does not seem to be emerging. Mutual accusations are in abundance but these will take us no-where. Is there a strategy for drawing up a road map to bring academia and Industry nearer to each other? Obviously not! Hence, some steps are necessary for evolving a strategy to bridge the academia-industry gap.

The problem is too complex when treated in all its raminifications. As a first step, why not "specifics" be tackled rather than whole-sale generalities. Academia from Universities and Laboratories often point out in their research publications the specific problems of Industry or Agriculture or Medicine where their results could be "specifically" useful. In fact, most of the research papers do so but those statements are too vague. Further, the industrial users are not able to spot out the relevant information in the "vast jungle" of research publications. Academia often approached industries seeking their indulgence in some of their laboratory-level or proto-type level devices. The very nature of such inventions is generally devoid of detailed steps and problems involved in the mass-scale industrial production. Hence, industries do not find these attractive as they are looking for quick returns for their investments. On the other hand, Industries do have problems which are prohibiting them to enter into innovative new products or to have good quality control of their products. Have industries tried to give details of their "specific" scientific problems to which academia may have an access? Generally No! Therefore, a fall out of such a default on the part of industries is that the academia has no method of knowing of any "specific" industrial problems which they can solve. Certainly it will be of immense value if the academia could know of such "specific" demands of industries in which the individual scientist has the expertise. This may catalyse goal oriented meaningful research.

This editorial has no intention of drawing up a detailed "road map" for industry-academia interaction. However, we wish to invite suggestions about the manner in which this journal may assist in catalyzing the over-all scientific development of the country. We certainly would invite industrial and service-sector scientists to prepare technical papers upon the scientific problems faced by them, results of their attempts to solve those and to highlight issues seeking involvement of "academia". This journal has a wide circulation encompassing more than 2000 individual scientists and many more scientists through libraries. We hope the exposure of "specific" industrial issues to such

a varied and vast academia (viz., Fellows/Members of the National Academy of Sciences, India) through this journal may help the cause of indigenous technology development. A small beginning with a zeal and positive attitude is the key to success. The journal can provide the forum but the initiative lies with you !!.

Girjesh Govil
Jai Pal Mittal
Suresh Chandra

The views expressed here are solely those of one of the Editors and do not necessarily reflect those of the Academy or the Institute where he works.

Cross-hole seismic tomography-A geophysical tool for detecting mine galleries

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Abstract

The data acquisition configuration plays a major role in imaging the subsurface lithostratigraphic units by seismic transmission tomography. Out of the three tomographic configurations *viz.* surface-to-borehole, borehole-to-surface and cross-hole, the later is generally used in the tomographic field investigations. Algorithms based on Simultaneous Iterative Reconstruction Technique and Simulated Evolution (both Genetic Algorithm and Evolutionary Programming) are developed for 2D seismic cross-hole tomography and are tested on real field settings to detect the abandoned coal galleries.

There is history of chronic mine fire and subsurface cave-ins in old abandoned coal mines like Raniganj Coalfield in West Bengal, India. These are caused by a number of unstable, unplanned, underground coal galleries at relatively shallow depths less than 50m. To prevent these hazards, the coal galleries are systematically detected for stabilizing. Shear wave cross-hole seismic tomography is applied for the purpose at Bansra Colliery at Raniganj Coalfield. The results presented here established cross-hole seismic tomography as a reliable tool to image voids and thus address environmental and geotechnical problems.

(Keywords : cross-hole seismic tomography/ simultaneous iterative reconstruction technique (SIRT)/simulated evolution/genetic algorithm (GA)/evolutionary programming (EP)/raniganj coalfield.)

Introduction

Seismic cross-hole tomography provides a means of imaging the subsurface lithostratigraphic unit from the *P*- or *S*-wave first arrival traveltime data. The resolution of the estimated images in seismic tomography depends on the inversion schemes used, completeness of the data sets and the initially assigned values of the medium parameters in the iterative reconstruction techniques. Since optimal solutions are always aimed at, even from poor initial models, global optimization and search technique such as simulated evolution is applied for solving the imaging problem. Genetic algorithm and evolutionary programming techniques are implemented to tackle the complex geological settings using the common genetic operators like crossover and mutation. A low pass filter mutation is designed and applied by moving a '3×3'

mask over the individuals to speed up the search process.

The present discussion starts with a brief review of the simultaneous iterative reconstruction technique (SIRT). One forward modelling scheme[1] is developed for the implementation of the simulated evolution techniques using genetic algorithm (GA) and evolutionary programming (EP). The cross-hole tomographic imaging is tested on real field examples.

There is history of subsidence, surface cave-ins, mine fires, flooding, inundation and other kinds of environmental hazards related to shallow coal workings in the Raniganj Coalfield. In the mid 1980s a hydro-pneumatic sand stawing method was developed to fill in the abandoned galleries in the coalfield, but their exact locations were unknown. Unfortunately, most of this old coal workings being uncharted cannot be stabilized. An integrated surface, borehole and cross-hole geophysical method were undertaken in an effort to solve this problem. A wide spectrum of surface and borehole geophysical techniques were intended to establish a geophysical methodology that would be able to locate underground voids / galleries and hence enable siting of boreholes for stawing, as well as to estimate, as far as possible, the volume of the underground cavities for stabilization to control hazards. Micro-gravity, seismic reflection and refraction, electrical resistivity profiling, ground probing radar, shear-wave seismic tomography (SWST) and electrical resistivity tomography (ERT) were used. Surface methods were evaluated as means of quickly surveying wide areas, while borehole tomography methods envisioned as tools to provide more detailed 2- and 3-dimensional views of the galleries. The present investigation deals with the two-dimensional cross-borehole tomography for the underground imaging of the Bansra (BN) Colliery at Raniganj Coalfield.

Cross-Hole Tomographic Algorithms

Simultaneous Iterative reconstruction technique

For seismic cross-hole tomography, the traveltimes of the seismic *P*- or *S*-waves are measured in the field for travelling from source locations in one borehole to the receiver locations in another borehole. Seismic raypaths generally bend if the velocity varies from node to node in the grid. Curved ray tomography is, therefore, required if the bending is significant. The amount of bending depends on the magnitude of the velocity gradient and on the angle between the gradient and the raypath. The tomographic reconstruction is a calculated set of seismic velocities for the pixel grid that minimizes the errors between the calculated and the measured traveltimes. The forward calculation of traveltime involves accurate estimation of raypath segment in each pixel.

Raypath segment and traveltime in the pixel

The raypath within the cell depends mainly on two aspects: (i) the velocity gradient within the cell, and (ii) the angle between the raypath and the velocity gradient. For simplicity, the velocity gradient within the cell is taken as constant and is assumed parallel to the positive Z-axis. If the velocity gradient is small or the raypath is nearly parallel to the gradient, the raypath is almost straight. Otherwise, the raypath is an arc of a circle.

Now, considering a raypath segment having an entry point P with the co-ordinates (X_P, Z_P), the exit point Q with the co-ordinates (X_Q, Z_Q) and the velocity gradient dV/dZ within the cell as shown in Fig. 1(a) can be written as,

$$X_Q = X_P + \int_{Z_P}^{Z_Q} (\frac{dx}{dz})dz \qquad (1)$$

If the ray at P (Fig. 1a) makes an angle θ_P with the positive Z-axis pointing downwards and V_P be the velocity at P, eqn. (1) can be rewritten as,

$$X_Q = X_P + \int_{Z_P}^{Z_Q} \frac{V(\sin\theta_P / V_P)}{\sqrt{1 - V^2(\sin\theta_P / V_P)^2}} dz \qquad (2)$$

Substituting $V = V_P + (dV/dZ)(Z - Z_P)$ in eqn. (2), integrating and rearranging the terms the following is obtained,

$$X_Q - \left[X_P + \frac{V_P \cos\theta_P}{(dV/dZ)\sin\theta_P}\right] = -\sqrt{\left[\frac{V_P}{(dV/dZ)\sin\theta_P}\right]^2 - \left[Z_Q - (Z_P - \frac{V_P}{dV/dZ})\right]^2} \qquad (3)$$

Equation (3) shows that the raypath within the cell is an arc of a circle with radius R expressed as,

$$R = \frac{V_P}{(dV/dZ)\sin\theta_P} \qquad (4)$$

and the center C with co-ordinates (X_C, Z_C) defined as,

$$X_C = X_P + \frac{V_P \cos\theta_P}{(dV/dZ)\sin\theta_P},$$

$$Z_C = Z_P - \frac{V_P}{dV/dZ} \qquad (5)$$

The exit point Q of the ray can be found out from the intersection of this arc and the pixel boundary.

The ray segment length ℓ within the cell can be defined as,

$$\ell = 2R\sin^{-1}\left[\frac{\sqrt{(X_Q - X_P)^2 + (Z_Q - Z_P)^2}}{2R}\right] \qquad (6)$$

The traveltime t along the raypath under consideration can be expressed in terms of a line integral such that,

$$t = \int_{Z_P}^{Z_Q} (\frac{1}{V})\frac{d\ell}{dZ} dZ \qquad (7)$$

Differentiating eqn. (6) with respect to Z and substituting the expressions for $d\ell/dZ$ and V in eqn. (7), integrating and rearranging the terms, one can estimate t from the relation,

$$t = \frac{0.5}{dV/dZ} \ell n\left[\frac{(1+\cos\theta_Q)(1-\cos\theta_P)}{(1+\cos\theta_Q)(1+\cos\theta_P)}\right] \qquad (8)$$

Thus the raypath segment ℓ and the corresponding traveltime t in a pixel can be estimated using the expressions (6) and (8) respectively.

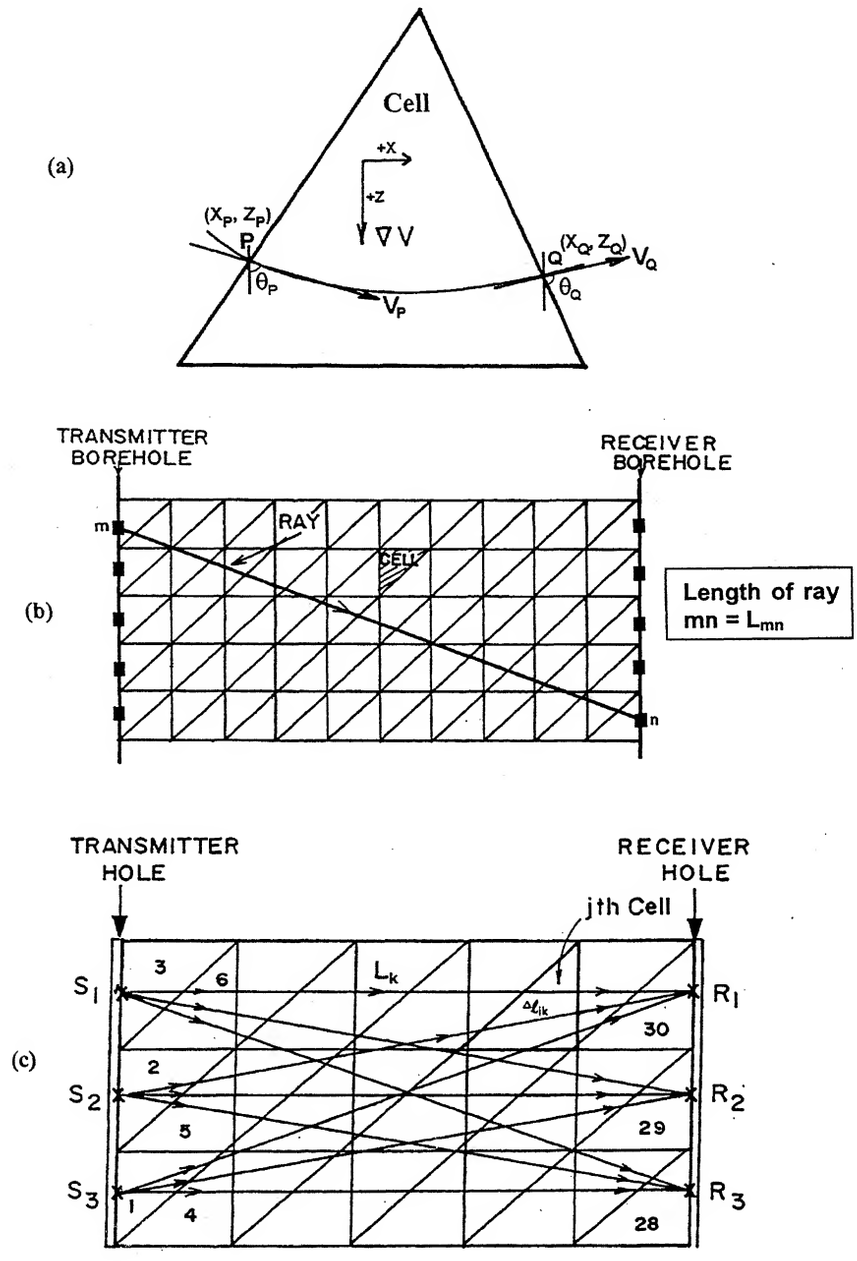


Fig. 1– Ray tracing and Simple Back Projection geometry : (a) ray-tracing in a cell, (b) initial model parameterization by Wong's method and (c) pixel and ray distribution in the enclosed region between the boreholes.

Initial model estimate

In the present investigation the back projection method[2] is used for this purpose. The raypaths are assumed to be straight.

Let L_{mn} be the length of the straight raypath joining the source m and receiver n, as shown in Fig. 1(b), and T_{mn} be the recorded first arrival time taken by the ray to travel from the source m to receiver n. Then, the average velocity for the entire region can be written as,

$$\bar{V} = \frac{\sum_m \sum_n L_{mn}}{\sum_m \sum_n T_{mn}} \qquad (9)$$

With $\bar{V}$ taken as the initial velocity distribution of the model region, SIRT is used for solving the cross-hole tomographic problem as discussed below.

SIRT

In SIRT the cross section of the model space to be imaged is divided into a number of triangular cells as shown in Fig. 1(c) and an initial velocity value is assigned to each cell. Direct raypaths are traced through the cross section for all recorded source-receiver pairs and the respective traveltimes calculated. The differences between the observed and the calculated traveltimes are then distributed along each raypath as a correction to the slowness (reciprocal of velocity) in each cell intersected by the ray. This is done simultaneously for all rays. So the slowness change actually applied to each cell is the average of the corrections calculated for each ray that intersects the cell. Thus, a new slowness or velocity field is generated. One proceeds by iterating through the same procedure: ray tracing through the new velocity field, comparing the observed and calculated traveltimes and averaging the corrections for each cell to revise the velocity field. The mathematical formulation of SIRT follows that of Dines and Lytle[3].

Simulated Evolution

Forward problem

The heart of each tomographic inversion method is to solve the forward problem so that one can calculate the error norm and its derivative efficiently with respect to the model parameters. Since the forward algorithm based on reciprocity and Fermat's principles[4,5] use a dynamic programming approach to take care of the curved ray geometry, it is implemented in the present traveltime calculations[1].

In this method, the traveltime map is established over a grid space by considering four time values, two of which are from the neighboring grid points, while

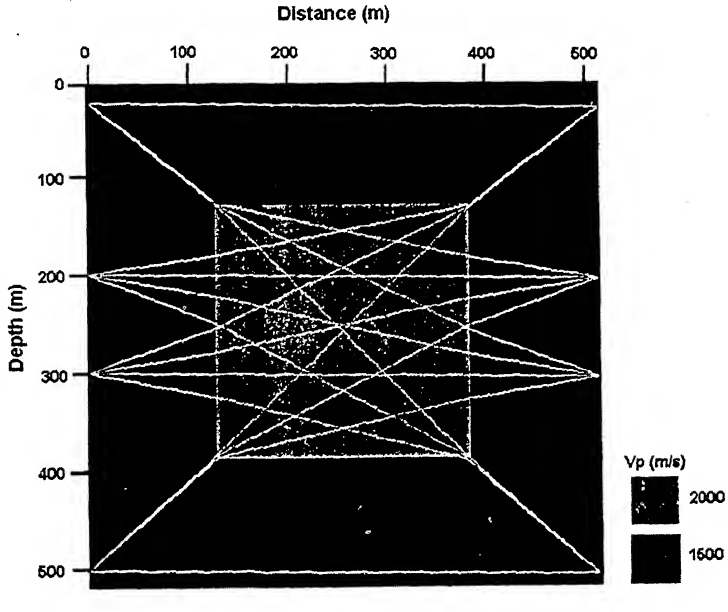


Fig. 2–The demonstration of ray-tracing through an intrusive high velocity square.

the other two are calculated by considering the intersection of the raypath with the nearest row and column. The points of intersection are determined by the root bisection method[1]. The ray-tracing through a high velocity square intrusive model (Vp = 2 km/s) in a low velocity medium with P-wave velocity of 1.5 km/s is shown in the raster image of Fig. 2 using this forward algorithm for 16 source-receiver pairs in the cross-hole configuration.

Simulated evolution algorithms

The formulation of the tomographic problem using optimization and the process of evolution in biology has much in common. Genetic algorithms[6,7] are analogous to the biological processes, since they are based on the principle of natural selection and genetics.

Compared with the traditional methods such as calculus-based and enumerative strategies, the evolutionary algorithm is robust, global and generally simple to apply. Currently there are three main avenues of research in simulated evolution namely; genetic algorithm, evolution strategies and evolutionary programming of which GA and EP are implemented in the present investigation.

Genetic algorithm

The objective of the genetic algorithm here is to evolve the subsurface 2-D velocity distribution model in the sampled space that would give rise to the traveltime data observed in the field. The forward modelling program based on the reciprocity principle is invoked by the genetic algorithm routine to calculate the traveltimes for each individual velocity model in a population for the subsequent calculation of the fitness of that individual.

Generation of population - The model parameter values are coded in the binary form. An individual in a population is a structure consisting of the velocity matrix randomly generated using an 8-bit binary representation. The population consists of many such individuals, an assembly of possible solutions.

Fitness function - The fitness function of an individual is taken as the reciprocal of the rms error between the traveltimes calculated for the individual and those observed in the field (or calculated for the original structure). The rms error is determined for each and every individual velocity model by invoking the forward modelling routine to compute the traveltimes. If t_{ij} (j = 1 to n) were the traveltime for the jth source-receiver pair in the ith individual velocity model, the rms error can be expressed as,

$$\varepsilon_i = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(t'_j - t_{ij})^2} \qquad (10)$$

where t'_j is the traveltime for the jth ray in the original structure. The population of the velocity models is then sorted in an ascending order of the rms error to yield a population with individuals sorted in the descending order of fitness values.

Genetic operators-In the present implementation of the genetic algorithm, three genetic operators are used, namely crossover, mutation and a low pass filter mutation.

Crossover-The individuals are taken one by one from the best 25% of the population to be paired with an individual

chosen randomly from the remaining population. The crossover point is also chosen randomly. The offspring generated by crossover replace the individuals having the lowest fitness. The entire population is re-sorted and the individuals are ranked based on their fitness values.

Mutation-Depending on the mutation rate, an individual is chosen randomly from the population by leaving the best 10% of the individuals intact. This ensures system stability as the solution is approached. The mutation is done using 'Gray coding'. A mutation rate of 1% is found to yield faster convergence and is, therefore, used in the synthetic and real field examples presented here. However different mutation rates are used for the computation of statistical uncertainty in the final solution of the real field examples.

Low pass filter mutation-To speed up the search process by allowing the small regions to grow faster a '3×3' low-pass filter mutation operation is performed. A '3×3' window is first placed on the slowness matrix with the first element at the center of the window. The velocity that occurs most frequently among all the elements falling within the window replaces the velocity in this element. In case of a tie, that is when more than one velocity occurs most frequently, any one of them is chosen randomly. The window then moves over to the next element in the row and the operation is repeated. This operation is performed sequentially row-wise over the entire velocity matrix. The regions that the genetic algorithm has started forming 'grow' in this operation.

Evolutionary programming

Mutation being the main genetic operator in evolutionary programming scheme the operation is performed using *Gray coding*. The advantage of *Gray coding* is that the binary representation of two consecutive *Gray coded* numbers differs by only one bit thereby allowing a smooth variation of the model slowness. But in the simple binary coding we may need to change several bits to increment a model slowness value by only one unit. *Gray codes* are generated by forming *bitwise exclusive or* of an integer i with the integer part of $i/2$.

In the evolutionary programming scheme, the mutation is performed in the following manner.

(1) The top 10% of the ranked individuals are not considered for mutation, as these are the fittest of the population.

The individuals to be mutated are selected randomly depending upon the user-specified mute rate. The number of cells to be flipped in the velocity matrix of any such individual is calculated using a Gaussian distribution function given as,

$$p = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2\left(\frac{\varepsilon-\mu}{\sigma}\right)^2} \qquad (11)$$

where ε is the rms error of the selected individual and p is the probability of mutation.

The limits of the distribution are taken as 10^{-1} and 10^{-8}, where the values of p are 1.0 and 0.01 respectively. These limits define the values of μ and σ for the distribution curve.

(2) At each mutation operation, a cell of the velocity matrix of the selected individual is chosen randomly.

(3) The value of the variable velocity code of the cell is then converted into the *Gray code*.

(4) A position is randomly selected at which the bit has to be flipped and converted back to the binary code.

Finally, the ranked individuals are sorted for low pass filter mutation to speed up the search process.

Detection of Mine Galleries

Geology and test site

The full sequence of the Raniganj Formation in the Gondwana super group covers ten regionally correlatable coal seams having the nomenclature *R-I* to *R-X* with local names in different areas. The exploited coal seams, which are being geophysically investigated[8] are:

a. North Searsole Colliery – Kenda Bottom (R-V) seam

b. Bansra Colliery – Purandip (R-VII Bottom) seam.

c. Dhandadih Colliery – Jambad top (R-VIII Top) seam.

Out of the above only Bansra Colliery is considered in the present paper.

Local geology

The Purandip coal seam (2.61 – 2.95m thick) being worked by board and pillar method occurs at a depth of 17m. Ground level varies from 85 to 90m above M.S.L. Bansra has the highest relief among all the three sites. The dip of the coal seam is 1.2° SSW. A mica-peridotite dyke/fault barrier occurs in the north of the area under investigation. A cover of about 1m of topsoil and 6 to 10m of weathered bedrock is observed. Locally the weathered sandstone is outcropping. In the area south of the Grand Trunk Road in the Bansra Colliery area, the Purandip Coal Seam is devoid of any workings. Recent drilling indicates the presence of the Purandip seam (11.77 to 19.74m depths) under 4.45m of topsoil and 7.32m of weathered bedrock. Highly weathered zones are also detected suggesting important lateral heterogeneities.

Drilling investigations

Drilling for seismic tomographic surveys in the Bansra Colliery was undertaken and completed at the locations indicated in Fig. 3. According to the requirement of the geometry of the tomographic surveys, drilling was completed to depths of about 20m below the target seams. The holes were located at the centre of the target pillars. The boreholes hit the pillars in most of the cases confirming the accuracy of the surveys. The lithologs of the boreholes are illustrated in the geological cross sections between each pair of the boreholes in Fig. 4(a) [BH-005 to 006] and (b) [BH-005 to 007] for the colliery.

It is evident from these sections of Fig. 4 that, in general there is a fining upward sequence comprising of sandstones, alternating shales and sandstones, shales and finally coal from bottom upwards below the coal seams and a coarsening upward sequence in the reverse order above the coal. The cross sections also illustrate a very low dip of strata.

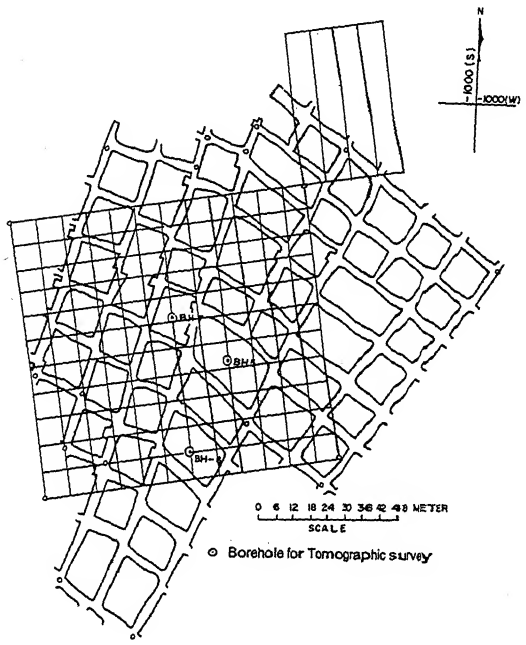


Fig. 3– Mine plan of Bansra Colliery with the boreholes for the tomographic survey.

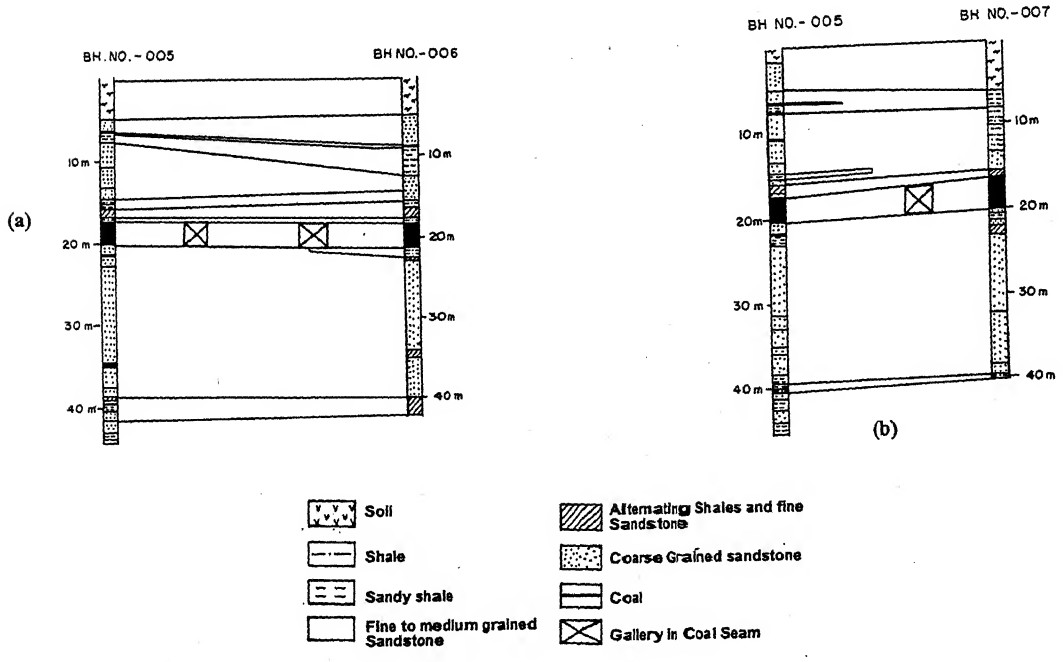


Fig. 4– Lithologs for (a) BH-005 to BH-006, (b) BH-005 to BH–007 at Bansra. The gallery positions in the Purandip coal seam are also depicted

Seismic Tomography Survey

Equipment

The instrumentation used in the SWST experiment consists of one borehole shear-wave generating hammer system, four borehole shear-wave geophone (3-component) with a natural frequency of 40Hz, one BISON Seismograph Model 9024, and one 5Kg sledge hammer as surface source.

Field Parameters

In the first cross-hole experiment, sources Tz are located in BH-005 and the receivers Rz in BH-006 and BH-007. The position of Tz varies from a depth of 10 to 30 m at an interval of 2m. The same geometry is applied to both the Rz positions. This means a total of 568 traveltimes (with 3 components each) are picked. The number of stacks for up and down blows varies from 3 to 5. The second cross-hole data set contains 576 traveltimes (3 component traces) with Tz being located in BH-007 and Rz in BH-005 and 006. The depth of Tz varies from 10 to 32 m at intervals of 2m and that of Rz also the same. The number of blows (up and down) varies from 5 to 10. The sample interval was set at 0.1 ms for the broad frequency band of 30-250 Hz. A sample summed cross-hole data for 142 traces (12 shots and 12 receivers, 2 killed traces) between BH-005 and BH-006 is presented in Fig. 5. The traveltime databases for cross-hole BH-005 to 006 and BH-005 to 007 are presented in Fig. 6(a) and (b) respectively in the form of residual traveltime surfaces[9]. The homogeneous *S*-wave velocities, in this case, calculated by the back projection method, are found to be 1.3 km/s for cross-hole BH-005 to 006 and 0.9 km/s for cross-hole BH-005 to 007. The average shear-wave velocity versus receiver depth profile at different shot depths calculated from cross-borehole data BH-005 to 006 and BH-005 to BH-007 as shown in Fig. 7(a) and (b) respectively present an estimate of *Vs* varying between 0.9 to 1.9 km/s approximately. The horizontal velocity models as displayed in Fig. 8(a) and (b) respectively for cross-hole BH-005 to 006 and BH-005 to 007 also depict the similar range.

Interpretation

The depth of investigation in this case is about 32m as the coal seam lies within that region. For SIRT algorithm the subsurface regions, $40.4\times22m^2$ and $26.7\times22m^2$ enclosed by the boreholes BH-005 to BH-006 and BH-005 to BH-007 are divided into 20×13 and 15×13 grids respectively. In both the cases, 12 source-receiver pairs at 2m intervals are used to acquire the data.

The cross-hole tomographic survey is done in two phases: (i) BH-005 to BH-006, and (ii) BH-005 to BH-007. The source-receiver distributions in both the cases are depicted in Fig. 9(a) and (b). The initial velocity estimates of the model by back projection method are 1.3 and 0.9 km/s, respectively. In case of cross-hole BH-005 to BH-006, two low velocity regions could be identified with the velocity ranging between 0.3-0.50 km/s as shown in Fig. 9(a), whereas in the cross-hole tomogram of the region between BH-005 and BH-007 only one low velocity zone with the velocity ranging between 0.3-0.6 km/s is visible as depicted in Fig. 9(b). The rms error curves for these two cross-hole configurations are displayed in Fig. 9(c). For GA and EP the subsurface regions of $40.4\times22m^2$ (between BH-005 and 006) and

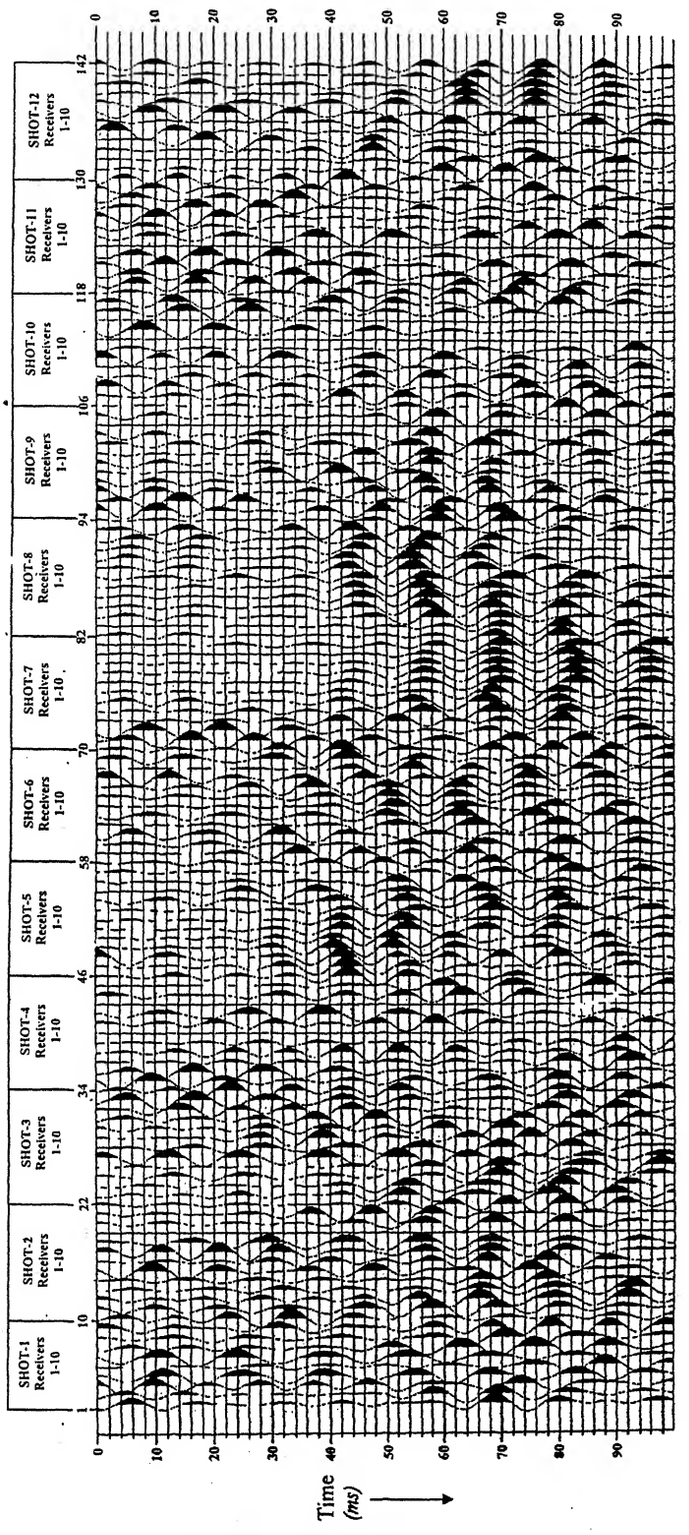


Fig. 5– Crosshole BH-005 to BH-006 seismogram at Bansra

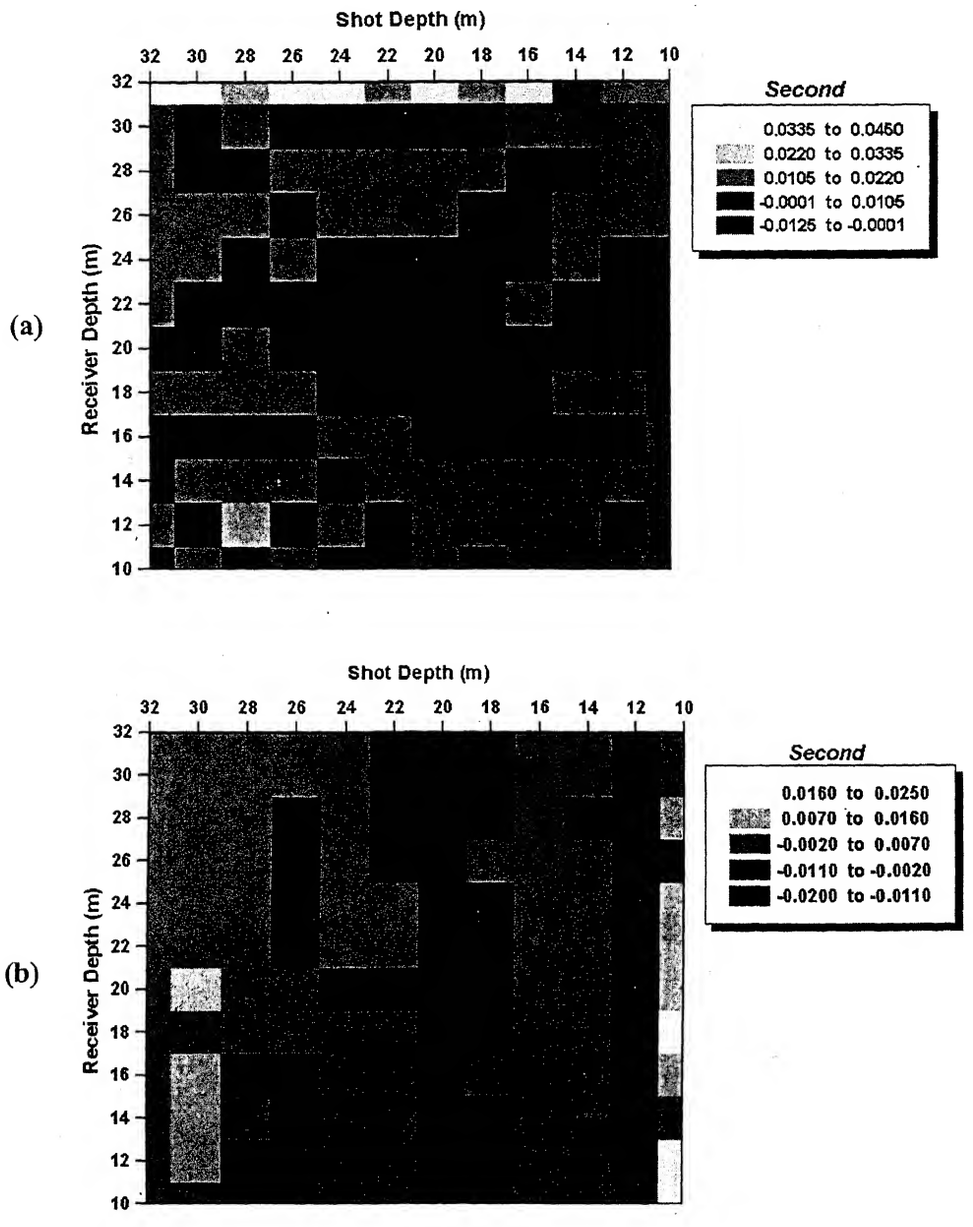
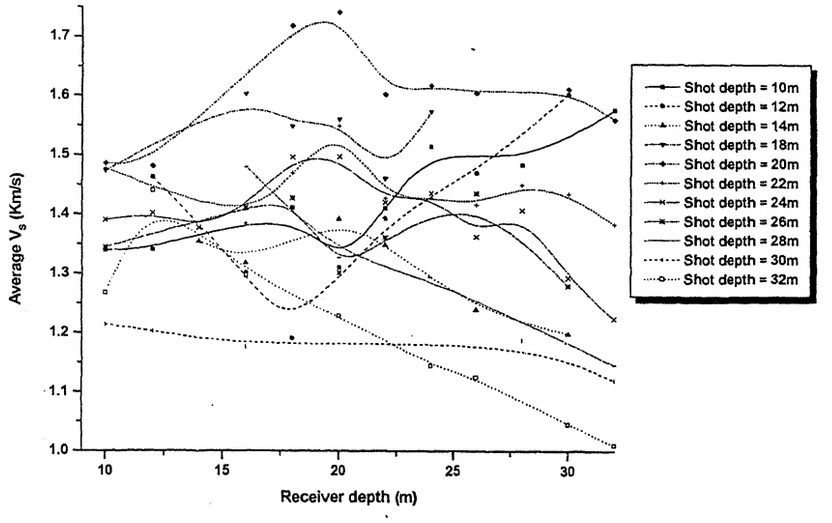


Fig. 6–Raster display of the residual traveltime surface generated from the S-wave first arrival traveltime data for (a) cross-hole BH-005 to BH-006 and (b) cross-hole BH-005 to BH-007 at Bansra.

(a)



(b)

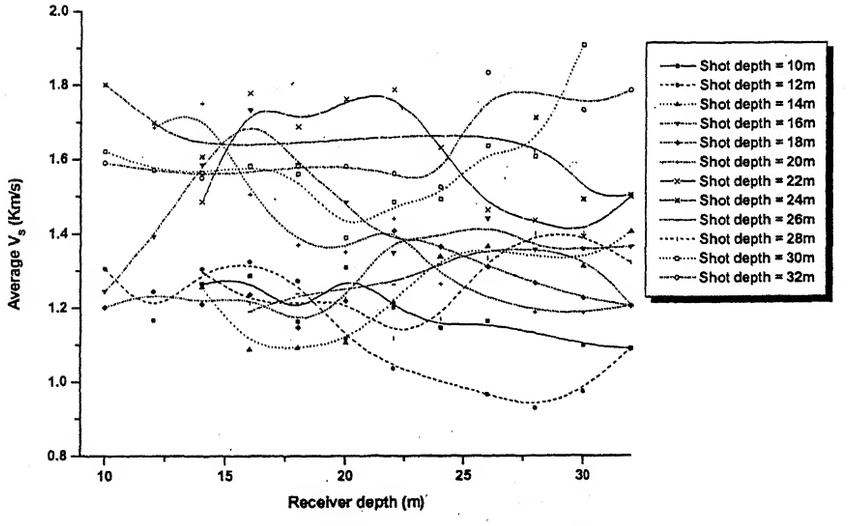
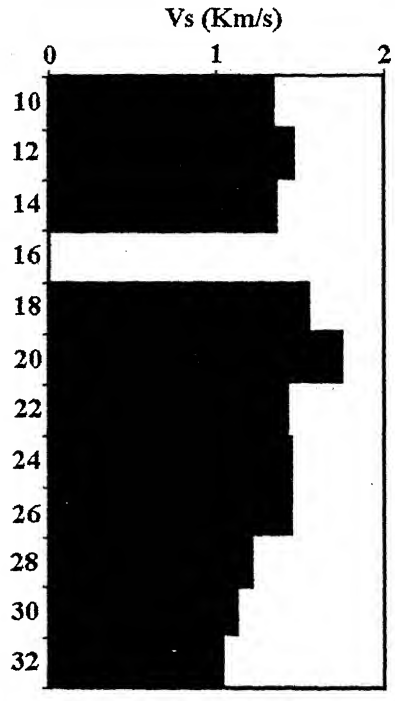
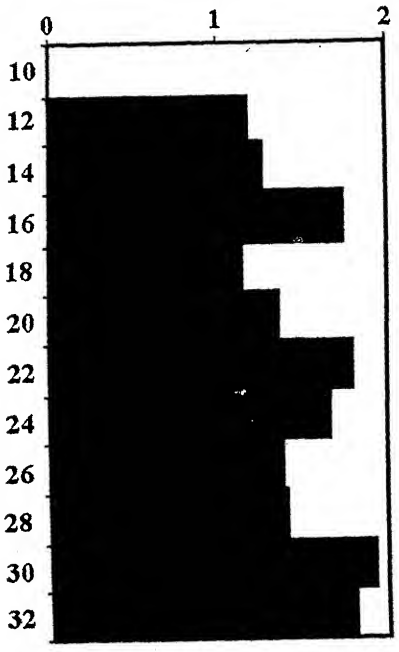


Fig. 7–The average shear-wave velocity versus receiver depth profile for cross-hole geometry (a) BH-005 to BH-006 and (b) BH-005 to BH-007 at Bansra Colliery.



Borehole BH-005 to BH-006

(a)



Borehole BH-005 to BH-007

(b)

Fig. 8–Horizontal velocity model of the subsurface region enclosed between the boreholes (a) BH-005 & BH-006 and (b) BH-005 & BH-007

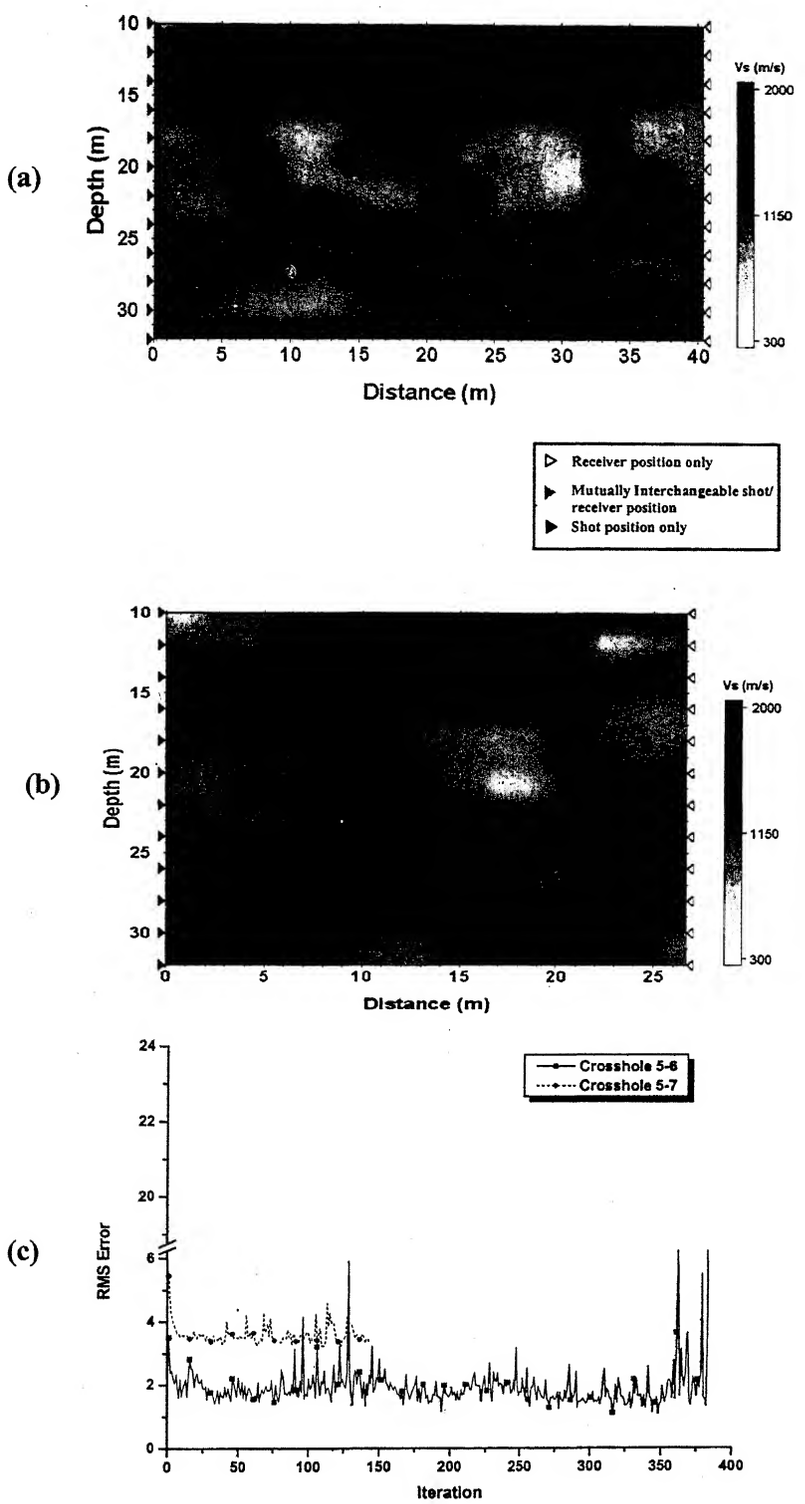


Fig. 9–Tomogram of the estimated subsurface lithostratigraphic units at Bansra Colliery, Raniganj Coalfield by : (a) Cross-hole BH-005 to BH-006, and (b) Cross-hole BH-005 to BH-007 configuration. (c) Error curves for the above two tomographic reconstruction.

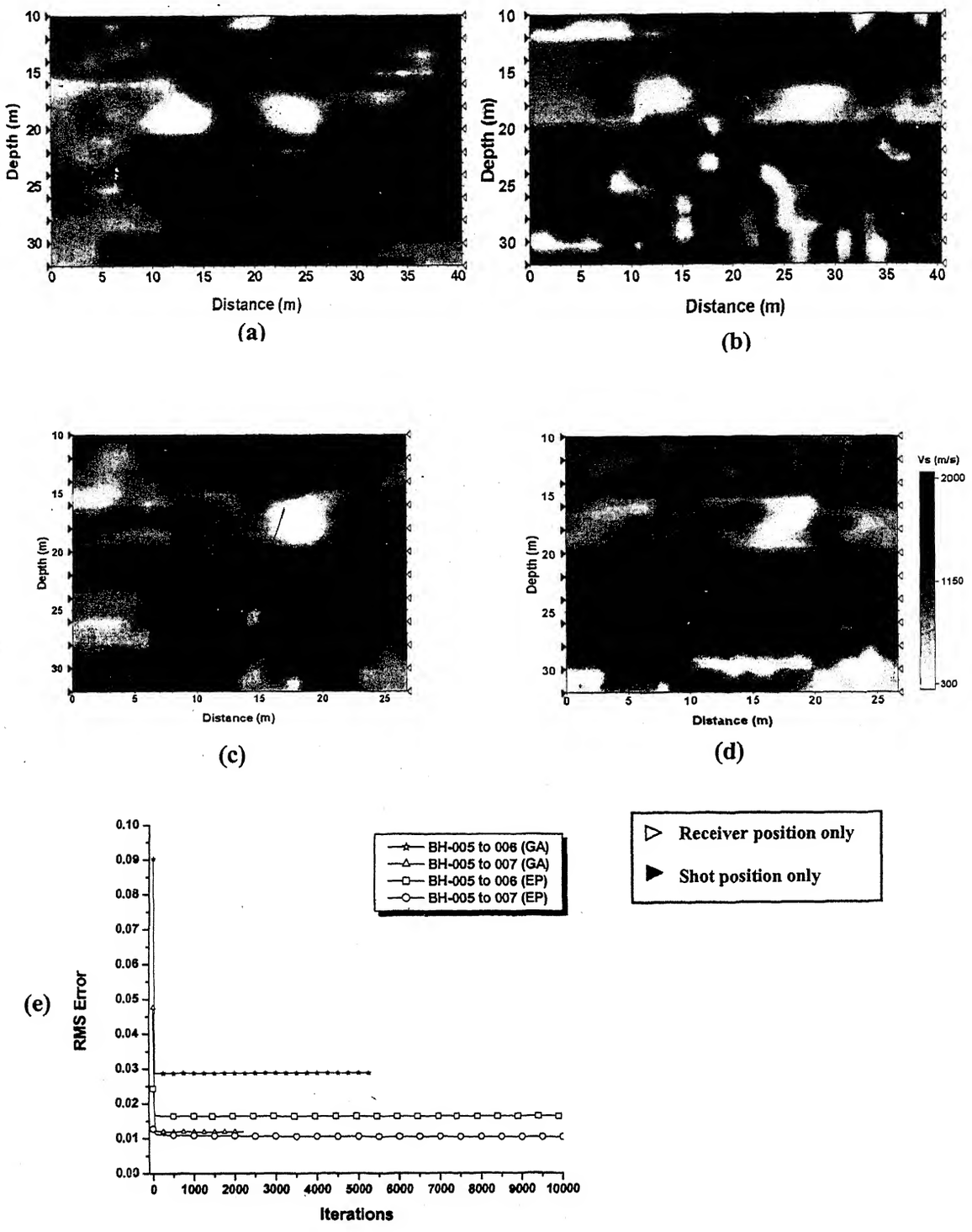


Fig. 10–Shear-wave velocity tomograms of the subsurface region between the boreholes BH-005 and 006 by (a) GA and (b) EP; BH-005 and 007 as evolved by (c) GA and (d) EP at Bansra Colliery. (e) RMS error curves for all the above cases.

$26.7 \times 22 m^2$ (between BH-005 and 007) are divided into 41×23 and 28×23 grids respectively for the tomographic reconstruction. The *S*-wave velocity tomograms of the region between BH-005 & 006 and that between BH-005 & 007 as evolved by the GA and EP schemes along with their rms error curves are depicted in Fig. 10(a), (b) (for BH-005 to 006), (c), (d) (for BH-005 to 007) and (e) respectively. In case of cross-hole BH-005 to BH-006, two low velocity regions could be identified with the velocity ranging between 0.3-0.45 km/s in the GA evolved tomogram (Fig. 10a) with a standard deviation of ±5.2% and 0.3 - 0.55 km/s in the EP evolved tomogram (Fig. 10b) with a standard deviation of ±5.5%; whereas in case of BH-005 to 007 only one low velocity zone could be detected in the velocity range of 0.3-0.4 km/s (Fig. 10c) with ±5.8% uncertainty and 0.3-0.5 km/s (Fig. 10d) with ±6.1% uncertainty respectively by both GA and EP schemes. The standard deviations are computed by using various combinations of population size, mutation rate, ± 15 % variation in the lower and upper velocity limits. On comparison with the lithologic sections of Fig. 4, the tomograms by SIRT, GA and EP predicted quite accurate low velocity zones (two in case of BH-005 to 006, and one in case of BH-005 to 007), the probable dry voids in the Purandip coal seam. However, the results by GA are more promising.

Conclusions

Using the traveltime inversions by simultaneous iterative reconstruction technique, genetic algorithm and evolutionary programming the subsurface could be imaged successfully. Both the synthetic and real field examples demonstrated the efficacy of the cross-hole seismic tomographic technique. It is indeed a useful tool for detecting mining hazards in the form of voids in the coal seam. While most of the existing tomographic imaging techniques are versatile, the simulated evolution algorithms are found to work over a large domain of problems. These techniques provide cost-effective means for mapping extreme heterogeneity and anisotropy associated with the abandoned coalmine workings.

Acknowledgements

The permission given by IDRC Canada and MGMI Kolkata to use cross-hole data in the Raniganj Coalfield is gratefully acknowledged.

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Plant tissue culture techniques in crop improvement

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Abstract

Plant tissue culture refers to the *in vitro* cultivation of plants, seeds, plants parts on nuetrient media under aseptic condition. The technique of plant tissue culture has developed to such a level that any plant species can be regenerated *in vitro* through several methodologies, particularly by micro-propagation. Tissue culture method has improved many crops with desirable characters include cereals, pulses, fruits, vegetables, spice, ornamentals, medicinal plants and forest trees.

(Keywords : embryo culture/micro-propagation/ protoplast fusion/ somatic hybrids/transgenic plants)

Plant tissue culture technique allows culturing of cells/ callus from any organ of the plant, i.e. root, stem, leaf, flower, part of the flower, embryo, endosperm, etc. Under appropriate /suitable experimental conditions, the cells/callus can be regenerated into whole plants. The technique offers tremendous opportunities in plant propagation, plant improvement, and production of plant with desirable agronomic characters. Hence, it has been possible to produce virus- free, salinity tolerant, herbicide resistant, disease resistant, and also to engineer plant with desirable traits. The role of plant tissue culture in meeting the ever increasing demand and requirements of man in field of agriculture, forest, medicine, horticulture is significant.

Theoretically, any part of the plant can be excised and cultured in vitro in such way that it can differentiate, forming a mass of cells called callus, from which many plant can be regenerated. On the other hand, with proper in vitro manipulation they do not form callus, but give rise to many true-to-true new plants. The plant cells from different plant parts/ tissues have the genetic capability to form all the parts of a whole plant through successive cell divisions and differentiation. This type of cellular feature /character is known as totipotency[1]. Todate several plant species representing annuals and perennials, herbaceous and woody species, monocots and dicots, self and cross pollinated groups that are vegetatively propagated and apomictic forms have been cultured in vitro and regenerated into complete plants[2,3]. The pioneer of plant tissue culture, Haberlandt in 1902, advocated that artificial embryos could be grown from the vegetative cells[4]. When callus tissues, produced on a solid medium are transferred to a liquid medium and grown with a constant stirring, in the presence of plant growth regulators, the cells separated and divide repeatedly,

forming a cell suspension. These cells can be filtered and plated on a solidified medium so that the single cells can grow into colonies from which organs and whole plants can be obtained. On the other hand, plant cell suspension, growing in bioreacters can produce secondary metabolites such as vitamins, enzymes, fragrances, falvours, pigments,etc.

In 1960, George Morel of France, in an attempt to isolate virus-free orchids from root tips, accidentally observed that the cultures proceeded through several stages of development, finally giving rise to a number of small embryo like structures called Protocorms. These protocorms, on reculturing gave rise to several plant within short time period. This method was soon exploited by commercial orchid-growers, because orchids are in general difficult to propagate by natural or conventional methods. Since then, this technique i.e. Clonal propagation has been widely used to propagate forest, horticultural, ornamental and agronomic plants. Clonal or asexual propagation of plants aims at producing genetically identical plants. This method can be accomplished by (i) formation of adventitious meristem, (ii) enhancing axillary buds or branching, and (iii) adventive embryo or embryoid formation[5]. The advantages of clonal propagation lie mainly in the way in which plant multiplication can be achieved and the number of plants that can be produced in a relatively short time, while saving the space. This can also be used for maintaning heterozygocity, to by pas sexual strerility or incompatibility. One of the most important applications of tissue culture techniques has been the use of meristem tip culture to eliminate viruses from the infected plants. Viruses exist in small numbers in meristematic cells and are not transmitted to progeny plants derived from the meristem in culture. Meristem culture has its major application in vegetatively propagated plants in which the parent plants are virus infected (e.g., casava, potato, sugarcane, strawberry, sweet potato, cauliflower, etc.). The advantages are i. propagation of clones throughout the year i.e. independence of season; ii. vegetative propagation of plant species difficult to propagate by conventional method; iii. elimination of viruses from infected stocks. High value ornamentals and foliage plants such as Chrysanthemum, Lilies, Gerbera, rose, carnation, orchids, anthuriums, Spathyphyllum, Diffenbachia, Cordyline, Ficus, Syngonium which are in great demand are routinely grown on a commercial basis using tissue culture techniques. Protocols have been developed for fruit crops such as pineapple, papaya, grapes apple, banana, and strawberry etc.[6].

More recently it has been possible to produce synthetic seeds in the laboratory. The technique involves the development of somatic embryos in vitro using a proper nutrient medium and subsequent encapsulation of these embryos in gel coat, an aqueous gel of sodium alginate which surrounds a polymer shell. Since millions of embryos can be produced in a single tube and hence, the technique has a potential to produce large number of synthetic seeds in a short time and space. The gel coat could carry along not only the embryos but also nutrients, agricultural chemical, nitrogen fixing bacteria to help seed germination, seedling growth and plant development[3].

Hybrid Embryo Rescue: In plant breeding program, when there is cross between two diverse species, the normal ovule development, in most cases is

adversely affected. The abnormalities can set in during i. Embryo development- There is an early embryonic stage at which development anomalies start to set in ovules harber underdeveloped embryos which have no more than a clump of vacuolated necrotic cells and results in shrunken aborted seeds. ii. Endosperm development: The embryos show nutritional dependence on the endosperm in unsuccessful crosses the endosperm starts to degenerate soon after fertilization, the embryo being deprived of its initial food supply[7]. These conditions can be over come through culture of the embryo in vitro. The embryo is excised carefully intact, without any damage, from mature or immature seeds, aseptic conditions should be used, and a sterile nutrient medium used for transference. Successful interspecific hybrids have been obtained in cotton, barley, tomato, rice , legume, flax and well known intergeneric hybrids include wheat x barley, wheat x rye, barley x rye, etc. Distant hybrids have also been obtained via embyo rescue in Carica and Citrus species. Some of the hybrid plants raised by embryo culture have recombined desirable genes such as earliness, disease resistance i.e.,viral, fungal, bacterial and nematode , and also pests i.e. aphid, shoot and fruit borer. Other applications of embryo culture are- production of haploids, overcoming seed dormancy, shortening of breeding cycle, prevention of embryo abortion with early ripening stone fruits and also clonal propagation[8,9].

Protoplast fusion: Agricultural research utilizes the hybridization process in plant breeding primarily for crop improvement. The term hybridization can be defined as the crossing of the germ or sex cells of two different organisms. In nature, crossing takes place between the plants of a species or at the most between individuals closely related plant species. An alternative to this sexual method of plant improvement is to manipulate plant system at cellular levels. In these systems, fertilization by sexual means can be by-passed and new characters introduced in plant by artificial fusion of two parent cells *in Vitro*.

Protoplast fusion leads to somatic hybridization is a novel technology in the plant tissue culture field with great potential in crop improvement programmes. The major areas of interest in plant breeding where this technique may be highly useful are, i. to combine characteristics of ortherwise sexually incompatible species/plants; ii. to produce cybrids and exploit cytoplasmic variability and iii. to facilitate genetic manipulation by the uptake of organelles, such as chloroplasts, nuclei, mitochondria, plasmids, etc. There has been considerable improvement in technique for protoplast fusion in recent years and several books and reviews on different aspects of somatic cell hybridization are now available[9].

Protoplast fusion methodology— Protoplast fusion begins with firm adhesion between the binding membrane of adjacent protoplasts. The steps involved are i. isolation of viable protoplasts, ii. fusion of protoplast, iii. selection, characterization and cloning of hybrids cells, iv. regeneration of somatic hybrids and v. evaluation and utilization of somatic hybrids. It is possible to isolate viable protoplasts in abundant quantities from a myriad of plant species, cell, tissue, and organ types i.e., especially from leaf. The surface sterilized tissues or organs are treated with a mixture of hydrolysing enzymes (cellulase, pectinase,), osmotic stabilizers (e.g. mannitol, sucrose),

membrane stabilizers (calcium chloride), buffer and nutrient solution which results in the digestion of cell wall and release and stabilization of the protoplasts.

Plant protoplasts can be fused by various methods, mechanically by pushing the protoplasts together, by using chemical fusogens such as sodium nitrate, calcium ions at high pH, dextran sulfate, fat-soluble substances(glyceroal mono-oleate) water – soluble polymers (polyethylene glycol or polyvinyl alcohol) or by induction of reversible membrane breakdown using an electric current. Of these polyethylene glycol (PEG) and electrofusion are found to be most effective methods of protoplast fusion. The PEG –induced protoplast fusion as non-specific has been reported to be very effective for protoplasts belonging to different species, genera or even families. For electrofusion, protoplasts are placed in a medium of low conductivity between two electrodes, and a high frequency alternating electric field (0.5-1.5 MHz) is applied across them. Heterokaryotic fusions were reported to occur at quite high frequencies, unfused protoplasts of the parental species as well as the products of homokaryotic fusions may grow vigorously, and dilute or eliminate the hybrid cells present in the population. To over come this problem, some methods have been developed to selectively recover the hybrid products among the unfused or fused homokaryotic parental protoplast populations. Some of these are: a. preferential growth of the somatic hybrids; b. albino complementation; c. resistant to antimetabolites; d. nutritional complementation; e. resistant auxotrophic mutants; f. metabolic inhibitors; g. flourescence-activated cell sorting[8,9]

After the standardization of conditions to selectively grow the hybrid cells, regeneration of plants from such cell needs special consideration. Carlson *et al.*[10], produced somatic hybrid from protoplast fusion of Nicotiana glauca and N. langsdorfii. Since then numerous such hybrids have been produced in other incompatible species. The somatic hybrids particularly those involving intraspecific protoplast fusion, show intermediate morphological features of the two parents. In a number of cases, hybrids/cybrids show characteristics of only one parent due to elimination of chromosomes or sorting out of plastomes of one parent. Cytogenetical and biochemical studies have been conducted to ascertain the hybrid nature. More recently, RFLP in combination with southern blot analysis has been used for analysis of nuclear and cytoplasmic genomes and have been very useful in verification of somatic hybrid plants. It is important to utilize the somatic hybrids in a breeding programme. The somatic hybrids could be used as new amphidiploid varieties[8,11].

Protoplast fusion has an additional advantage as it allows the mixing of different cytoplasms to obtain cybrids and may be cell organelle recombinants. Chloroplast and mitochondria, the two main important organelles are present in the cytoplasm, possess cp-DNA and mt-DNA respectively. These organelles besides being actively involved in carbon assimilation and respiration pathways, have genetic information of several agriculturally important traits such as male sterility, herbicide tolerance, and antibiotic or toxin resistance. Studies with cybrids started with model species belonging to the solanaceae. Sine then, a number of different methods have been employed to obtain cybrids i.e. inactivation of nuclear genome of one parent by X- or gamma irradiation or

by treatment with a metabolic inhibitor, fusion of normal protoplasts with subprotoplasts/cytoplasts and by the preferential elimination of chromosomes of one parent in hybrid following cell growth and proliferation.

The production of cybrids has been reported in Brassica, tobacco, citrus, petunia and carrot. From the point of view of plant breeding , remarkable success has been achieved regarding the incorporation of cytoplasmic male sterility(CMS, a mitochondrial feature) and herbicide tolerance genes (e.g. atrazine present in cp-DNA) in Brassica species.. It is possible to recover plants that contain chloroplast from one parent and mitochondria from the second parent. It is feasible to engineer cells with novel genome/cp-DNA or genome/mt-DNA combinations in a wide range of plant where protoplast technology is well developed[7,8].

The most important application of protoplast fusion to the plant breeder is that it provides the means to exchange germplasm, particularly across sexually incompatible species[12]. There are two types of protoplast fusion: i. Symmetrical hybridization involving fusion of normal protoplasts of both the parents with complete cellular genomes, and ii. Asymmetric hybridization wherein only a few chromosomes, subchromosome fragment(s), or a small fraction of the chromosome or a few genes are transferred from the donor to the recipient species.

Symmetrical fusions are usually beneficial when fusion partners are closely related phylogenetically. If the fusion partners become more distantly related, the heterokaryons usually lack synchrony in the mitotic cell cycle and exhibit chromosome loss of one or both of the parents. This type of genomic incompatibility at the somatic level has been termed as "somatic incompatibility ", often leads to aberrant meiosis and infertility of pollen grains and egg.

Somaclonal variation: It is the naturally occurring genetic variation in plants regenerated from somatic cells grown in tissue culture. The variation stems from two sources: (i) it pre-exists in the explant tissue and (ii) it arises during the culture procedure itself. It has been successfully used to produce new varieties of crop plants i.e. tomatoes with higher solid content, carrot and celery with improved snaking characteristics such as sweetness, crunchiness, crispness; and also new types of coffee, beans, popcorn, cacoa beans, oilpalm, etc.[13].

In vitro selection: In tissue culture as plants could be regenerated from a single cell and millions of cells could be grown in a single culture vessel, and hence these could be effectively used for raising plants resistant to salinity, diseases, etc., in a space as small as a petriplate. A cell population with rapid growth and high plating efficiency at low- densities is necessary to select similar responses to those of the intact plants in the presence of toxic compound and should be able to regenerate intact plants. The genetic information selected at cellular level should be stable in the cell lines, and in the regenerated plants, and be transmitted to the progeny. For developing salt-tolerance , for example, technique involves the culture of cells on a proper nutrient medium containing inhibitory level/s of salt/s.

Suspension culture is the most frequently used system for selecting resistant cell lines. The conditions for selection are established through tests with

different concentrations of the compound, focusing on the effect on cell growth and survival. Cell /s colonies are selected that are capable of growing and dividing when exposed to toxic concentrations of the compound. Thus, cell and tissue cultures have been utilized as systems for testing phytotoxicity and studying the metabolization of herbicides.

Transgenic plants: Now, it is possible to isolate genes of interest from any source such as animals, microbes and plants, and to transfer them into the cells of desired plant species. The transformed cells are made to regenerate to whole plant. The plants, thus produced, are referred as Transgenic Plants and the procedure adapted is called Genetic engineering. Using this technique, plants resistant to insect/pests, diseases, viruses, etc. have been developed in many crop species. The procedure involves identification of desired gene (DNA segment); characterisation (Sequencing); cloning into desired plasmid; transformation (chemical, electroporation, biolistic, Agrobacterium-mediated); molecular characterization of transformed cells/plants; and the expression of the transgene[14,15,16]. Conventional methods of plant breeding allow transfer of genes over narrow range i.e. within a species. The techniques of gene transfer using recombinanat DNA technology, allow transfer of genes from even bacteria or insects to higher plants. This has increased immensely the possibilities of crop improvement. The first transgenic plants expressing engineered foreign genes were produced in tobacco since then, transgenic plants have been produced in over 90 species of flowering plants[15,16]

The production of large number of transgenic plants was though restricted initially to tobacco, petunia, tomato of the family Solanaceae, they are now available in a wide range of dicotyledonous plants, some of these are of economic value.

Herbicide resistance in transgenic plants- Due to increasing concern about contamination of the environment by herbicides, new herbicides are being developed that are safer and biodegradable. This has necessitated the development of resistance in crop plants against these new herbicides[17]. Herbicides , normally affect the processes like photosynthesis or biosynthesis of essential amino acids. Two approaches have been used for the development of resistant plants[17] : (i) In the first approach is that either the target molecules should become insensitive to herbicide or the target protein should be overproduced. (ii) in second a pathway is introduced that will detoxify the herbicide.

Modification of the target: the target has been modified for developing resistance for herbicides i.e., glyphosate, sulphonylureas and imidazolinones in case of petunia, tomato and tobacco, The expressing genes were isolated from plant or bacteria (Salmonella or E.coli, or tobacco or Arabidopsis) and transferred to crop plants. Detoxification or degradation of herbicide is the basis of selective use of herbicide, so that the latter will kill the weeds and not the crop. A number of detoxyfying enzymes have been identified in plants as well as in microbes[18]. Some of these include GST which detoxifies herbicide atrazine; nitrilase detoxifies the herbicide bromoxynil, PAT detoxifies the herbicide PPT. The genes have been identified in bacteria i.e., bxn, bar, obtained and transferred to crop plants(15).

Genes for resistance to insects, genes for protease inhibitors, genes for insecti-

cidal secondary metabolites, genes for resistance against viral, bacterial and fungal pathogens have been identified and incorporated in the crop plants like tobacco, tomato, lettuce, groundnut, pepper and in ornamentals i.e., Ageratum, Impatiens and Chrysanthemum.

The production of transgenic plant in monocotyledons was initially not possible due to limitation i.e., monocots were not infected by Agrobacterium. DNA uptake has been observed and regeneration protocols for crop like rice, maize, wheat, oats have been developed successfully during last few years.

In vitro production of haploids: the term haploid refers to those plants which possess a gametophytic number of chromosomes (single set) in their sporophytes. The interest in haploids stems largely from their potential in plant breeding, especially for the production of homozygous plants. Guha and Maheshwari[19] reported the direct development of embryos and plantlets from microspores of Datura innoxia by the culture of excised anthers. Since then, anthers containing immature pollen have been successfully cultured for a wide range of economically important plants. Haploid production through anther culture has been referred to as androgenesis.

Significance and uses:- In the breeding context, haploids are most useful as source of homozygous lines. The main advantage is the reduction in time to develop new varieties. A conventional plant breeding program takes about 6-8 years to develop a pure homozygous line, whereas by the use of anther/microspore culture the period can be reduced to few months or a year. Thus, homozygocity is achieved in the quickest possible way making genetic and breeding research much easier. Pure homozygous lines can be used for the production of hybrid development. Haploid cell cultures are useful material for studying somatic cell genetics, especially for mutation and cell modification. By the anther culture not only haploids but also plants of various ploidy levels and mutants are obtained and can be incorporated into the breeding programmes. By haploid induction followed by chromosome doubling it is possible to obtain exclusively male plants. For example, in Asparagus officinale male plants have a higher productivity and yield earlier in the season than female plants. Significance in the early release of varieties of wheat, rice, tobacco, Brassica etc for some/few agronomical features. Haploid production has been used for the introduction of disease and insect resistance genes into cultivars. An established cultivar is crossed with a donor for disease resistance. Either F1 or F2 anthers are plated and haploids are developed. These haploids are screened for resistance and then diploidized. Examples are in case of barley, resistance to yellow mosaic virus has been introduced into susceptible lines; rice for blast resistance; in tobacco for potato virus disease etc[20,21]

Apart from the above mentioned objectives, plant cell and tissue culture techniques can become handy in metabolite production in vitro, also in tissue preservation methods, viz., cryopreservation: for cell suspensions, embryonic suspensions, and to store plant embryos in a disease- free condition. Plant tissue culture in combination with cryopreservation has a great potential for long-term storage of germplasm and for germplasm exchange.

Human population is likely to double in about 35 years and more than 10 billion people will have to be fed, clothed and

provided with job under the conditions of shrinking land and water resources of agriculture, expanding abiotic and biotic stresses, increasing genetic erosion and raising cost of fuel energy reserves.[22] With a growing demand for the economic products of plant origin, relentless efforts are being made to enhance plant productivity and quality of produce and also to develop plants of agronomic value through newer technologies like that of plant tissue culture. Plant tissue culture is an essential component of Biotechnology which has contributed tremendously to crop improvement and has great potential for the future[23].

In India, tissue culture research began nearly four decades ago.. Today tissue culture technology is being exploited mainly for large scale production or micropropagation of elite plant material with desirable characteristics. Successful results have been obtained for forest trees, horticultural, floricultural and plantation crops. There are a number of R & D laboratories, which have perfected the technology for important horticultural, floricultural and plantation crops. These technologies are ready for commercialization and has contributed significantly towards the enhanced production of high quality plant material for the export market. A number of micropropagation industries were set up in India to cater mainly to the export market with an annual production of 50-60 million[24]

The tree species identified covered a wide spectrum which included trees of the desert and arid zone, tropical and temperate zone, leguminous trees and multipurpose tree species for timber, fuel, paper and pulp.

(a) Multipurpose species- Acacia nilotica, Alnus nepalensis, Hardwickia binata, Tamarindus indica, Dendrocalamus strictus, Bambusa arudinacea etc.

(b) High-value timber species- Tectona grandis, Shorea robusta, Dalbergia latifolia, Santalum album, Populus deltoides etc.

(c) Desert and Arid zone species- Tecomella undulata, Prosopis cineraria, Ziziphus numularia, Phoenix dactylifera, Acacia senegal, Sapindus trifoliatus, Wrightia arborea,Boswellia serrate etc.

(d) Temperate and Himalayan tree species- Pinus kesiya, Pinus roxburghii, Robina pseudocacia, Betula sp. Cedrus sp., etc.

The extensive support provided to the area of plant tissue culture by the Department of Biotechnology over the last one decade, which was initiated in the form of small network programme, has now expanded and reached a stage of commercial exploitation. The department has supported 150 projects for R & D in nearly 80 different Universities/ Research Institutes/ Organizations[24].

Micropropagation- Explants used for this study include the material from mature identified clones or seedlings. the protocols have been standardized and commercialized eg., Eucalyptus tereticonis, E. camaldulensis, E.citriodora, Tectona grandis, Dendrocalamus hamiltonii, Populus deltoides etc.

Organogenesis/embryogenesis-Explants used are mainly leaf tissues, mature or immature seeds, stem bits, cotyledons, zygotic embryos, shoot meristem, etc.

Studies on microbial association- In case of Cedrus deodora bacterial association resulted in enhanced germination and better survival of seedlings.

Germ plasm collection- Germplasm of different identified clones of many species have been collected are being preserved and protocols have been commercialized. the species are Calamus, Tumeric, Eucalyptus, Bamboo, Teak, Ginger, Cardamom, Betal vine, Long pepper, Black pepper etc.

Anther culture- Cocoa and Tea.

In plantation and spice crops, tissue culture techniques have been gainfully employed to increase productivity. Successful examples include banana, cardomon and black pepper at Kerala Agrticultural University and Calicut University. At BARC, for banana, cardamon and mulberry and the technology has been transfered to large scale. The Indian Institute of Rubber Research at Kottaaayam has standardized protocol for micropropagation of rubber. The Central Coffee research Institute , Coffee Board, for coffee[24].

Synthetic seeds were prepared in many plant species like Sandal wood with somatic embryos; mulberry with axillary buds; banana with shoot tip; cardamon with shoot tips ; cereals with somatic embryos at BARC. At BARC, tissue and /or cell cultures for the production of bioactive compounds have been established in Catharanthus roseus for amalicine, Rauwolfia serpentina for amaline, Castanospermum australe for tetra hydroxy indozinidine and Nothapodytes foetida for camptothecine which are highly medicinal[23]

The plant species being studied are nationally important with high economic potential for the tissue culture regeneration systems include beverages, endangered species(Aegle,Caseasria,Ceropegia,Curculigo,Excoecaria,Frerea,Gymnema,Hemidesmus etc), forest trees, horticultural crops (apple, banana, citrus, mango, strawberry), cash crops like sugarcane, ornamentals (chrysanthemum), Spice and condiments- (Cardamon, cinnamon, ginger, kala zira, nutmeg, pepper, saffron, clove, turmeric)[24].

In order to promote the large scale multiplication of tissue culture technology in various agro-climatic regions of the country, six hardening units have been established. This programme has successfully standardized protocols for tree species of economic and medicinal importance. Good number of (50,000 to 2.00 lak) plants Anogeissus spp., Capparis spp., Calligonum polygonoides, Celasstrus paniculatus, Leptodenia teticulata and Salvodora oleoides have already been produced and supplied to various agencies. The facility was also utilized for initiation of culture , multiplication and hardening of Azadirachta (neem), Aegle maarmelos (beal), Bacopa monieri (brahmi), Caralluma edulis (paimpa), Ceropegia bulbossa (khedual), Cymbopogon spp.(lemon grass), Lawsonia innermis (henna), Eucalyptus spp., Mommordica dioica (kakoda) ,Ephedra foliata (oontphogi), Withania spp. (ashwagandha and paneer bandh), Feronia limonia, Achras sapota (chikoo), Chlorophytum borivilianum (safed musali)[24].

In view of the tremendous success achieved at the two Tissue Culture Pilot Plants in terms of plantlet production and field evaluation, an urgent need has been felt to promote the commercialization of the Plant Tissue Culture Technology. The protocols developed by various research groups and standardized by the two Tissue

Culture Pilot Plants and hardening units are of commercial importance and it was felt that there is a need to set up a platform to make this available to the tissue culture industries/ entrepreneurs. In view of the existing expertise available at the two TCPPs, these were converted to Micro-propagation Technology Parks. The two MTPs (one at TERI, New Delhi and other at NCL, Pune)have been progressing very well and technologies perfected by them have been transferred to the industry. The emphasis of the parks is on forestry and horticultural crops, nearly 3.5 millions forest tree species have been produced and sent to various State departments covering an area of nearly 3700 ha. Field trials have been conducted at multi-locations in 18 states across the country. The species being produced through tissue culture are : Anogeissus spp., Bamboos, Eucalyptus, Leeucaena hybrids,Poplars,Paulownia. Horticultural species of Cordyline, Dieffenbachia, Ficus, Monstera, Philodendron, Rose, Dahlia, Pelargonium, Gerbera, Verbascum, Chrysanthemum, Banana, Strawberry, Potato and spice plants of ginger, cardamon, turmeric have also been produced.

Transgenic rice plants containing Cry IA(b) and Cry IA (c) genes have been obtained by using protoplast and particle bombardment methods. Indica rice CV IR-50 have been developed for salinity and drought tolerance harboring p5LS gene. Several male sterile transgenic lines were available in Brassica juncea for heterosis breeding. Different sources of CMS-inducing cytoplasms were transferred to cabbage, cauliflower and broccoli. Resistance lines of pigeonpea for heliothics via somatic embryogensis has been developed. Like wise transgenic lines of tobacco and tomato have been developed for many desirable features[24].

Recently, the MTPs concentrated on perfection of protocol, demonstration and service activites. Nearly 12 million plants have been produced and field planted over 9500 ha in different states in collaboration with Forest Departments/ Corporations, Agricultural Universities, and private sector organizations over 350 locations in India.Various states have used these tissue cultured plantlets in their afforestation programmes. The horticultural species that were produced during the period under consideration include fruit crops(banana, strawberry),cash crops(potato, sugarcane) vegetables and ornamentals like asparagus, carnation, dahlia, chrysanthemum, gerbera, geranium philodendron, verbascum etc[25].

Thus, plant tissue culture techniques plays important role in the development of crops by modification, multiplication and there by in the development of sustainable agriculture.

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Evaluation of bio-fungicidal properties of some plant extracts on the growth of *Schizophyllum commune*

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Abstract

Biofungicidal properties of different plant extracts on the growth of *Schizophyllum commune* were evaluated. Dried leaves of *Ageratum conyzoides*, *Azadirachta indica*, *Bryophyllum* sp. *Carum copticum*, *Catharanthus roseus*. *Ocimum sanctum*, *Parthenium hysterophorus*, *Withania somnifera*, and stem of *Cuscuta reflexa* were used against the mycelial growth.

Maximum inhibition of fungal growth was recorded in *Cuscuta reflexa* (98%) followed by *Ageratum conyzoides* (81%), where as *Withania somnifera* was least effective (24%). However, *Catharanthus roseus* was found to be a growth enhancer (-90%).

(Keywords : plant extract/ *schizophyllum commune*/ biofungicide)

Several higher plants and their constituents have shown success in plant disease control and are proved to be harmless and non-phytotoxic, unlike chemical fungicides. During recent years use of plant secondary metabolites for the control of fungi is gaining importance.

Therefore, in the present study an attempt has been made to observe the effect of different leaf and stem extracts on the growth of *Schizophyllum commune.*

It is a common lignicolous fungus, its caps often cover the entire surface of dead or dying trunks of various trees and shrubs, fallen branches and stumps. The mycelium of which penetrates the wood, decomposing the sapwood of trees and shrubs into a felt like substance. It even infests herbal root stocks and actively decomposes worked and treated wood. The mycelium of *Schizophyllum commune* is also the causal organism of a disease called basidio-neuromycosis and was isolated from the cerebro spinal fluid of a man in Brazil[1].

Fresh leaves from *Ageratum conyzoides, Azadirachta indica, Bryophyllum sp, Carum copticum, Catharanthus roseus, Ocimum sanctum, Parthenium hysterophorus, Withania somnifera* and stem of *Cuscuta reflexa* were washed with distilled water and dried at room temperature. To prepare stock solution the plant materials were separately crushed with mortor and pestle in distilled (w/v, 25g/100ml) and filtered with a muslin cloth and then through the Whatman filter paper no. 1. Extract 25% thus obtained was utilized for the experiments.

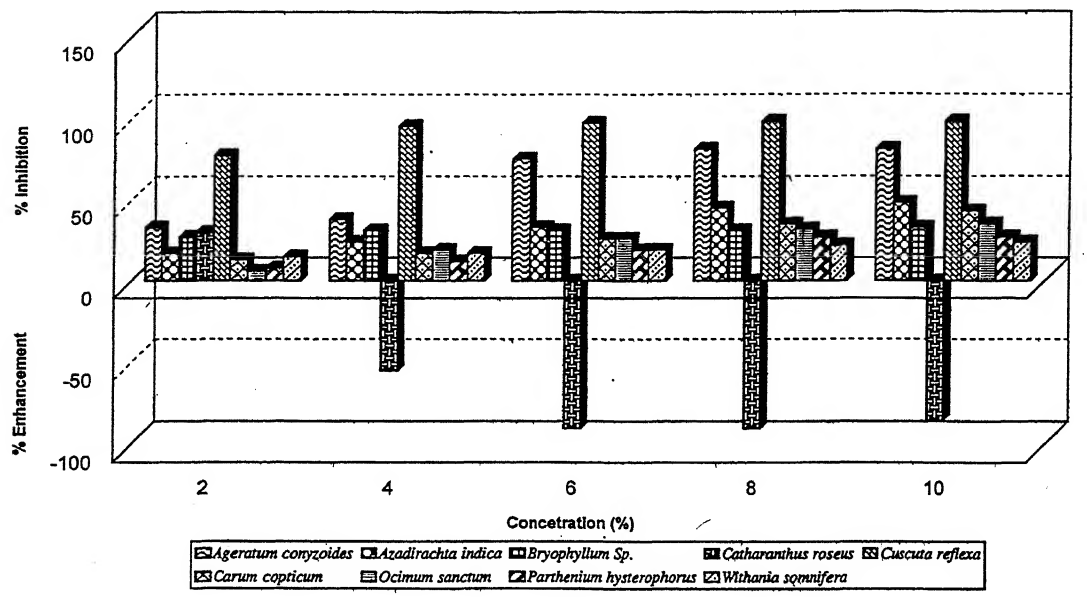

Fig.1-Effect of plant extracts on growth of *S. commune*

The test extracts in the concentrated form was taken and appropriate volume mixed with medium (PDA with 0.5% yeast extract) to obtain concentrations ranging from 2.0 to 10.0% in the final volume of 30 ml of medium. This 30 ml medium was dispensed into two 9cm. petriplates for replications [2-0]

Fruit bodies of *Schizophyllum commune*, collected from wood, was grown on the medium (PDA with 0.5% yeast extract). 1 cm diameter of mycelium discs were cut from 10 days old culture with cork borer and placed in the centre of each plate. Control sets were also prepared without plant extract. The plates were incubated at 25^0C ($\pm 1^0$C) and growth of colony was measured after 120hrs of inoculation. The radial growth of mycelium was measured at two points along the diameter of the plate and the mean of these two readings was taken as the diameter of the colony. The growth of the colony in control sets was compared with that of various treatments and the difference was converted into percent inhibition by following formula[3].

$$\text{Percent inhibition} = \frac{\text{diameter of control set-diameter of treated set}}{\text{diameter of control set}} \times 100$$

Out of the nine plants screened, eight test extracts exhibited fungitoxic properties, however, the leaf extract of *Catharanthus roseus* was found to be a growth enhancer (Fig.1). Maximum inhibition of fungal growth (98%) was recorded in *Cuscuta*

reflexa followed by *Ageratum conyzoides* (81%). The least inhibition of growth was recorded in *Withania somnifera* (24%).

To conclude extracts from different plant sources could be used separately or in combination. This can result in control of disease at lower concentration of extracts. Due to their strong fungitoxicity, readily available sources, nonphytotoxicity and biodegradability, fungitoxicant from plants do have a promising future. As a growth enhancer leaf extract of *Catharanthus roseus* can be used for useful fungi. Inhibitory effects of extract of *Cuscuta reflexa* was not reported earlier and it gave the excellent result.

Acknowledgement

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A possible biological control of obnoxious weed *Parthenium hysterophorus*, a new record

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Abstract

During the survey of insect and fungal infestation in *P. hysterophorus* (Congress grass, Gajar ghas) plants in July-September, 2003, it was observed that large number of insects were feeding on *Parthenium* leaves and flowers. Percentage of damage was very high i.e. up to 90%. The insect is identified as *Listronotus setosipennis* belonging to curculionid group. It has been reported here for the first time from India.

(Keywords: *Parthenium / Listronotus setosipennis*)

Parthenium hysterophorus L. (Congress grass, Gajar ghas) is a major Indian weed of Neotropical origin. It is an obnoxious weed, indigenous to North and Central America, Maxico and West Indies. In India it was first reported from Pune (Rao, 1956)[1]. It has now spread throughout most of the Indian subcontinent (Aneja *et al.*)[2] and now considered to be the principal terrestrial weed in India (Dhawan *et al*)[3].

P. hysterophorus is toxic to livestock and causes allergenic responses, such as respiratory malfunctions and dermatitis in susceptible human (Towers *et al.*)[4]. It has been calculated that over 40% of population in Bangalore has been sensitised to *Parthenium* pollen (Towers and Subha Rao)[5].

During a survey of insect and fungal infestation in *P. hysterophorus* plants in July to September, 2003, it has been detected that large numbers of insects were found feeding on *Parthenium* leaves and flowers in number of localities in and around Allahabad, India. Adult insects chew the leaves, flowers and other plant parts, thereby damaging the plant. Percentage of damage is very high i.e. up to 90%. Therefore it can be used as a biological agent for controlling the *Parthenium* weed. The detailed work is in progress and will be discussed in a separate paper.

The insect is identified as *Listronotus setosipennis* belonging to curculionid beetle group. It is a stem boring weevil. It is being reported here for the first time from India. Earlier it was reported from Mexico (1997).

During field observation, a number of insects (Fig. 1) were found feeding ferociously the weed plant (Fig. 2). The extent of damage could be observed in the Fig. 3.

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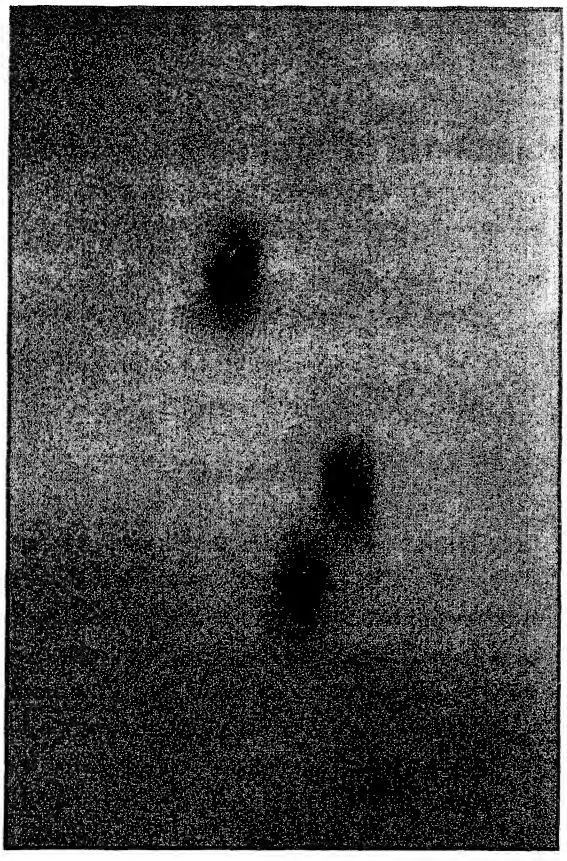
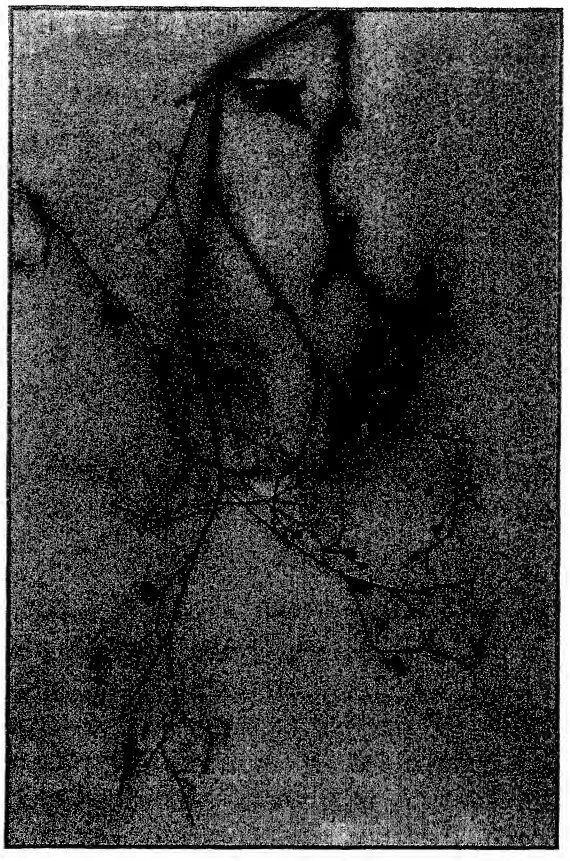


Photograph No. 1
Insect : *Listronotus setosipennis*



Photograph No. 3
Damage caused by insect.

Photograph No. 2
Number of Insects feeding ferociously the weed plants

Modelling for HIV spread due to needles

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Abstract

The use of unsterilized needles is the second most serious transmission mode (TM2) for HIV infection. The spread of virus through this mode is a phemenon involving many complexities due to the magnitude and extent the needles are used by persons of all age groups. This article proposes a simple methodology to estimate the number of HIV infections in a given region due to the use of clinical injections.

(Keywords : clinical injection/HIV infection/ Sterilized needles)

The use of infected needles (TM2) is the dominating mode of HIV spread in most parts of the world including North Africa, Middle East, South and South East Asia, East Asia and Pacific accounting for nearly 10 million seropositives and for 25% of the total seropositives estimated across the globe[1]. In India, as at the end of 2001, based on HIV sentinel serosurveillance data, 4 million people were estimated to be HIV infected and atleast ten thousand seropositives were among Intravenous Drug Abusers. Of the 8 States, Maharastra (Mumbai) tops the list in the HIV prevalence with 42% seropositives noted among drug abusers[2]. The two major components of the HIV spread in TM2 are A : Drug abuse *via* needle sharing, B : Use of un-sterilized needles for clinical injections.

Some basic differences between components A and B are as follows : 1) Component A is an intentional act though illegal and involves confidentiality while component B is unintentional clinical act widely performed. 2) Activity A is restricted to a subpopulation confined to a geographical area while B is unrestricted and has its impact throughout the region. 3) Component A is age dependent. Mostly the young males and females are involved here while B is age independent. Since the components A and B have drastically different characteristics it is not desirable to estimate together the total number of HIV infections. Instead, a component-wise estimation can be attempted which may be used for planning separate interventions. Finally, the estimates can be pooled to provide an overall estimate. Some work has been reported on component A regarding probability of an infected needle (Stimson[3]; Brickner *et al.*,[4]; Kaplan[5]) and in respect of number of infections among drug abusers (Rao and Srivenkataramana[6]) while little is known about B. For component A, we suggest Kaplan's procedure while for

component B we develop below a workable method.

Kaplan's method : The dynamics of needle infection in component A has been modeled by Kaplan[5]. He postulated a two-state Markov process to capture the essence of needle infection process as the needle alternates between uninfected and infected states in accordance with some stochastic process. It is assumed that transmission of the uninfected needle to the infected state occurs at a rate λ while infected needles return to the uninfected state at a rate μ. To keep the model simple, it is assumed that the duration of needle circulation after introduction follows an exponential distribution with mean τ. Then the probability that a randomly selected needle is infected is shown to be

$$P(\tau) = \frac{P_o + \lambda\tau}{1 + (\lambda + \mu)\tau} \qquad (1)$$

where P_o is the probability that the needle is infected at the time of introduction. Rao and Srivenkataramana[7] have used eqn. (1) to estimate the number of HIV infections in blood transfusion. Also, Rao and Srivenkataramana[6] have proposed a method using covariate randomized responses to estimate the number of HIV infections among drug abusers.

Estimation of component B : This component has a few other features which include the following : i) The first use of needle poses no risk. Only its reuse provides scope for new infection. ii) Infection depends on the time interval between successive uses as HIV survives for only a few minutes in media other than blood. No reliable estimate of this is available in the literature, except that it is short. iii) Proper sterilization before use eliminates risk of infection. But sterilization, though it is mandatory, may not be done due to negligence or ignorance. iv) The number of infections caused depends directly on the duration of the needle in circulation and the number of reuses.

Keeping the above features in view we develop a method to estimate the annual number of infections due to needles used in clinics. The key parameters of the model are

θ_1 : probability of needle reuse

θ_2 : probability of non-sterilization before reuse and

θ_3 : HIV transmission rate in TM2.

If a needle is reused w times and infection takes place in the i^{th} reuse, then only $(w - i)$ further reuses have the infection risk where $i = 1, 2, \ldots, w$. Let X denote the number of times the needle is in infected state during w reuses and k be the average number. Since the probability of needle infection is small relative to the number of reuses, we may assume X to follow a Poisson distribution. Since the number of reuses is limited to w, due to, for example, the needle getting blunt, it is necessary to truncate the Poisson density at $X = w$. This leads to the density

$$\phi(x) = P(X = x) = \frac{e^{-K} \; k^x / x!}{1 - \sum_{w+1}^{\infty} e^{-K} \; k^x / x!};$$

$$(x = 0,1,2,3 \ldots\ldots w) \qquad (2)$$

Let k' denote the mean of the truncated Poisson distribution specified by eqn.(2).

The case $X = 0$ presents the 'best' scenario while the cases $X \geq 1$ put together cover the 'worst' scenario. The average situation is represented by k' infected states per needle. This reasoning can be used to develop three possible scenarios accordingly. Let $\phi_1 = P(X = 0)$; $\phi_2 = P(X = k')$ and $\phi_3 = P(X \geq 1) = 1 - \phi_1$ be the respective probabilities associated with the scenarios. For planning purposes, average scenario may be considered, in which case k', the mean of the truncated density specified in eqn. (2) has to be computed.

This may be obtained as follows :

$$k' = \sum_{x=0}^{w} \left[\frac{x.e^{-k} \; k^x/x!}{1 - \sum_{w+1}^{\infty} e^{-K} \; k^x/x!} \right]$$

$$= e^{-k}.k \sum_{x=1}^{w} \left[\frac{k^{x-1}/(x-1)!}{\sum_{x=0}^{w} e^{-k} \; k^x/x!} \right]$$

To evaluate the number of infections in the different scenarios, we define the following events :

E_1 : {reuse of a needle},

E_2 : {non-sterilization of a needle}

E_3 : {transmission of infection by an infeted needle}

For a new infection to take place, a needle should be in infected state followed by the occurrence of the events E_1, E_2 and E_3 in that order. The probability of this compound event is

$\theta = (\theta_1.\theta_2).\theta_3$ (assuming $E_i (i = 1, 2, 3)$ to be independent events)

To arrive at the number of persons infected in a given region ($n(t)$) due to needle reuse we require the total number of needles put to use in all the clinics. Let this be denoted by $m(t)$. Then estimates of $n(t)$ in the three scenarios are provided by

$$\hat{n}_i(t) = m(t).\phi_i.\hat{\theta}; \qquad i = 1,2,3 \qquad (3)$$

Knowledge of parameters : One source for the value of $m(t)$ is the drug association while the parameters θ_1 and θ_2 are to be assessed by experts. The value of θ_3 can be taken to be 1 unless there is some information to the contrary. The choice of k will be difficult in the absence of any definite information on it and also due to complexity in collecting the relevant data which estimate k. In any case the value of k depends on (i) the total circulation time of a needle and (ii) the expected number of reuses of a needle. In fact k and w are positively correlated. As such the value of k may be taken to be equal to $(w-1)/3$.

Conclusion : The estimate $\hat{n}_1(t)$ provides a lower bound for the number of infections. On the other hand, $\hat{n}_3(t)$ is an upper bound since ϕ_3 will be the highest probability, which is required for planning interventions adequately. However, for all practical purposes, $\hat{n}_2(t)$ will provide a working estimate. Also $\hat{n}_2(t)$ will be useful to assess the spread of HIV due to component B of TM2, to measure the magnitude of the epidemic in the given region and to plan intervention strategies. It is possible that a particular needle in circulation is reused by the same person.

The impact of this is to reduce the number of *new* infections due to the needle.

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An efficient procedure for optimization of linear objective function subject to fuzzy relation equations with max-product composition

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Abstract

An optimization model with a linear objective function subject to a system of fuzzy relation equations (FRE) is considered. Since, feasible domain is non-convex; the traditional methods for solving this linear programming problem (l.p.p.) can not be applied. The problem is transformed into 0-1 integer programming problem. Based on the upper bound and rearranging the structure of the problem, we present a backward jump-tracking branch-and-bound technique for solving this optimization problem. It is remarked that taking the advantage of special structure of feasible domain, the problem size can be reduced so that the effort to solve the problem is minimized. A numerical example is provided to illustrate our scheme.

(Keywords : Fuzzy relation equations / Integer programming / Branch-and-bound method)

1. Introduction

Let $A=[a_{ij}],0 \leq a_{ij} \leq 1$, be an $(m\times n)$ – dimensional fuzzy matrix, $b = (b_1,\ldots,b_n)$, $0 \leq b_j \leq 1$, be an n-dimensional vector, then the following system of FRE is defined by A and b :

$$x \, o A = b \qquad (1)$$

where "o" represents the *max-product* composition. The resolution of (1) means to find the solution vector $x=(x_1,\ldots,x_m)$, $0\leq x_i\leq 1$,such that

$$\max_{i=1,\ldots,m} (x_i . a_{ij}) = b_j \quad \text{for } j=1,\ldots,n. \qquad (2)$$

Let $c= (c_1,\ldots,c_m) \in R^m$ be an m-dimensional vector where c_i represents the weight (or cost) associated with variable x_i, for $i=1,..,m$. The optimization problem of our interest is

$$\text{minimize } Z = \sum_{i=1}^{m} c_i x_i$$

$$\text{subject to} \quad x \, o A = b \qquad (3)$$

$$0 \leq x_i \leq 1.$$

It is to be noted that l. p.p. in (3) differs in nature from regular l. p.p. The space of constraints is non-convex in general[1,2]. Therefore, traditional methods for solving the classical l.p.p., viz, simplex method and

interior-point method can not be applied to this problem.

Sanchez's work[3] has thrown some light on the important applications of FRE. Thereafter, several authors[1,2,4-14,16-20] have further enlarged this theory and tried to explore the problem of resolution and its applications with many papers. Studies on investigating fuzzy relation equations with max-T-norm composition or generalized connectives can be found in literature[6,7,14,16]. Pedrycz[15] provided the existence condition for the max-T-norm composition. It was also shown that the max-product composition can yield a faster response than max-min composition in the fuzzy logic controller.

Fang and Li's[9] is the first paper on the study of the fuzzy relation equation with linear objective function. They proposed 0-1 integer programming based branch-and bound with jump-tracking technique to solve the linear optimization problem. Studies in the literature[10,11,12,18] are the further contributions in this area. An efficient solution procedure for complete set of minimal solutions of fuzzy relation equations with max-product can be found in literature[12]. Their procedure is based on identification and elimination of the 'nonminimal' solutions. Wu *et. al.*[18] proposed the upper bound technique for solving a linear optimization problem with max-min composite fuzzy relation equations as constraints. Solving a system of fuzzy relation equations completely is hard problem. According to literature[1,2,9], a complete solution of fuzzy relation equations can be obtained by a unique maximum and finite number of minimal solutions. These minimal solutions are combinatorial in problem size. In this communication, we propose a procedure that takes care of the problem size and determines the optimal solution of the optimization problem without explicitly computing all the minimal solutions. We, first, give the characterization of feasible domain and optimal solution. Then, we describe the upper bound technique to solve the problem with negative and positive costs (the conflicting decision problem). This procedure shows its advantage over the procedure described in literature[18].

The rest of the communication is arranged as follows. In Section 2, some characteristics of feasible domain of system of fuzzy relation equations with max-product composition are explored. Section 3, studies the effect of cost vector to decompose the optimization problem into sub-problems. In Section 4, upper bound technique is described and a procedure to reduce the problem size is remarked.Step-by-step algorithm is also presented. One example is solved in Section 5 to illustrate the whole procedure. Conclusions are given in the last section.

2. Characterization of the feasible domain

Let $X(A, b) = \{ x = (x_1,\ldots,x_m) \in R^m \mid x \circ A = b, x_i \in [0,1] \ \forall i \in I \}$ be the feasible domain. Let $x^1, x^2 \in X(A,b)$. $x^1 \leq x^2$ if and only if $x_i^1 \leq x_i^2 \ \forall i \in I$. Thus, $(X(A,b), \leq)$ becomes a poset. Moreover, $\hat{x} \in X(A, b)$ is called maximum solution if $x \leq \hat{x}$ for all $x \in X(A, b)$. Also, $\check{x} \in X(A, b)$ is called a minimal solution, if $\check{x} \leq x$ implies $x = \check{x}, \forall x \in X(A, b)$.Clearly, $X(A,b)$ is a lattice. According to literature[1,2,9], when $X(A, b)$ is non- empty, it can be completely determined by a unique maximum and a finite number of minimal solutions.

The maximum solution can be obtained by applying the following operation:

$$\hat{x}=A@b=[\bigwedge_{j=1}^{n} a_{ij}\ @b_j]_{i\varepsilon I} \qquad (4)$$

where

$$a_{ij}\ @\ b_j = \begin{cases} 1 & , a_{ij}\le b_j \\ b_j/a_{ij} & , a_{ij}>b_j \end{cases} \qquad (5)$$

Let $\check{X}(A, b)$ be the set of all minimal solutions, then

$$X(A,b)=\bigcup_{\check{x}\in\check{X}(A,b)} \{x\varepsilon X \mid \check{x}\le x\le \hat{x}\} \qquad (6)$$

Following useful lemma are proved in Lzogala *et al.*[11] .

Lemma1 : If $x \in X(A,b)$, then for each $j \in J$ and $b_j \neq 0$, there exists $i_0 \in I$ such that $x_{i_0}.a_{i_0j}= b_j$ and $x.a_{ij} \le b_j$, otherwise.

Proof : Let $b_j \neq 0$ and $x\,o\,A = b$, then $\max_{i\,\varepsilon\,I}(x_i\ .a_{ij}) = b_j$ for $j \in J$. This means for each $j\ \varepsilon\ J$, $x_i\ .a_{ij} \le b_j$ .In order to satisfy equality, there exists at least one $i \in I$, say i_0 , such that $x_{i_0}\ .\ a_{i_0j} = b_j$ and hence $x_{i_0}.a_{i_0j}= b_j$.□

Definition 1 : A constraint $j_0 \in J$ is called *scares or binding* constraint, if for $x \in X(A, b)$ and $i \in I, x_i\ .a_{ij_0} = b_{j_0}$.

Definition 3 : For a solution $x \in X(A, b)$ and $i_0 \in I$ and $i \neq i_0$, x_{i_0} is called *binding variable* if $x_{i_0}.a_{i_0j}= b_j$ and $x_i.a_{ij} \le b_j$, for all other $i \in I$.

Let $X(A, b) \neq \varphi$. Define

$$I_j=[i\in I \mid \hat{x}_i.a_{ij}=b_j\ \},\quad \forall\ j\ \in J. \qquad (7)$$

$$J_i=\{j\in J \mid \hat{x}_i.a_{ij}=b_j\} \qquad \forall\ i\in I \qquad (8)$$

$$\Lambda = I_1\times.....\times I_n. \qquad (9)$$

Clearly, I_j is the index set of all binding variables that satisfy constraint j and $\|\Lambda\|$ is used to determine the complexity of the algorithm.

Lemma 2 : If $X(A, b) \neq \varphi$, then $I_j \neq \varphi, \forall j \in J$.

Proof : Proof is consequence of lemma 1.□

Lemma 3 : If $\| I_j\| = 1$, then $\hat{x}_i = \check{x}_i = b_j/a_{ij}$ for $i \in I$.

Proof : Since x_i ,$i \in I_j$,is the only variable that satisfies the constraint j, it can take only one value equal to b_j /a_{ij} and hence the lemma.□

Lemma 4 : For $j, j' \in J_i$, $b_j / a_{ij} = b_{j'} /a_{ij}$

Proof : Since x_i is the only variable that satisfies the constraints j and j', i.e. $x_i\ .\ a_{ij} = b_j$ and $x_i\ .\ a_{ij'} = b_{j'}$. Therefore, $x_i = b_j /a_{ij} = b_{j'} /a_{ij}$. □

3. The Sub- Problems

The cost vector $c = (\ c_1,.....,c_m\ ) \in R^m$. We can choose two vectors $c' = (c'_1,.....c'_m) \ge 0$ and $c'' = (c''_1,.....,c''_m) \le 0$ in R^m such that $c = c' + c''$. Writing $Z = Z' + Z''$. The original problem is decomposed into two sub-problems as given below :

$$\text{minimize } Z' = \sum_{i=1}^{m} c'_i\ x_i$$

subject to

$$x\,o\,A=b,\ 0\le x_i\le 1. \qquad (10)$$

and

$$\text{minimize } Z'' = \sum_{i=1}^{m} c_i'' \, x_i$$

subject to

$$x \; o \; A = b, \; 0 \le x_i \le 1. \qquad (11).$$

where

$$c_i' = \begin{cases} c_i & \text{if } c_i \ge 0 \\ 0 & \text{if } c_i < 0 \end{cases} \quad \forall i \in I. \qquad (12)$$

$$c_i'' = \begin{cases} 0 & \text{if } c_i \ge 0 \\ c_i & \text{if } c_i < 0 \end{cases} \quad \forall i \in I \; (13)$$

The following two lemma are proved in literature[9,11].

Lemma 5 : If $c_i'' \le 0$, $\forall i \in I$, then ,for the sub- problem (11), $\hat{x}$ is an optimal solution.

Lemma 6 : If $c' \ge 0$, $\forall i \in I$, then, for sub-problem (10), one of the minimal solutions, say $\breve{x}^*$, is an optimal solution.

The final solution $x^* = (x^*_1, \ldots, x^*_n)$ can be ,thus, obtained by combining $\hat{x}$ and $\breve{x}^*$ as

$$x_i^* = \begin{cases} \breve{x}^* & \text{if } c_i \ge 0 \\ \hat{x} & \text{if } c_i \le 0 \end{cases} \quad \forall i \in I. \qquad (14)$$

and

$$Z^* = \sum_{i=1}^{m} (c_i' \breve{x}_i^* + c_i'' \hat{x}_i). \qquad (15)$$

4. The Upper Bound Technique and Algorithm

In this Section we will describe the procedure to solve the sub-problem (10).

Notice that $\hat{x} \in X(A, b) \neq \phi$. For any $x \in X(A, b)$, $x_i \le \hat{x}_i \;\; \forall \;\; i \in I$ has an upper bound. Because the costs are positive, the sub-problem (10) will have an initial upper bound.

To explain the technique, first we will arrange the elements in c' and b so that

$c_1' \le c_2' \le \ldots\ldots \le c_m'$ and $b_1 \le b_2 \le \ldots\ldots \le b_n$ because the "branches" in the solution tree generated by backward branch-and-bound procedure likely fathomed by the incumbent upper bound.

According to literature[9,18], the associated 0-1 integer programming problem to the problem (10) can be written as

$$\min Z' = \sum_{i=1}^{m} c_i' \max_{j \in J} \{\frac{b_j}{a_{ij}} .. y_{ij}\}$$

$$\text{s.t.} \quad \sum_{i \in I_j} y_{ij} = 1 \quad \forall j \in J \qquad (16)$$

$$y_{ij} = 0 \text{ or } 1 \qquad \forall i \in I_j, \; j \in J.$$

where I_j , $\forall j \in J$ and J_i , $\forall i \in I$ are defined in (7) ,(8) respectively. The constraints of (16) reveal the following observation. In each constraints of (16), exactly one decision variable is set to be 1 and the others are 0. Hence, we have $| I_j |$ ways to select a decision variable to be one in the constraint j. Thus, the number of feasible solutions for (16) is $\| \Lambda \| = | I_1 | \times \ldots\ldots \times | I_n |$. This quantity shows the complexity of the integer programming problem adopted in paper[18].

Remark : We can reduce the problem size by making following observations.

Let $\bar{I} = \{ i \in I_j \mid | I_j | = 1, \; \forall j \in J \}$. $i \in \bar{I}$ will satisfy all the constraints of J_i.

Define $\bar{J} = \bigcup_{i \in \bar{I}} J_i$ Discard the row $i \in \bar{I}$ and column $j \in \bar{J}$ from the matrix A and column $j \in \bar{J}$ from the matrix b.(This operation can be performed in basis matrix V, generated later)

Define $I' = I - \bar{I}$, $J' = J - \bar{J}$ and

$$\wedge' = \underset{j \in J'}{\times} I_j.$$

Clearly, $\| \wedge' \| \leq \| \wedge \|$.

From the lemma 3 and 4 , $x_i^* = \hat{x}_i = b_j'$, for all $i \in \bar{I}$, and $Z_i' = c_i b_j', j \in J_i$.

If $\bar{I}$ and $\bar{J}$ are non-empty, replace I by $\bar{I}$ and J by $\bar{J}$.

Now we describe upper bound based 0-1 integer programming method. We will describe procedure to compute the initial upper bound for 0-1 integer programming problem (16).

Define the basis matrix $V = [v_{ij}]$ where

$$v_{ij} = \begin{cases} b_j' & \text{if } i \in I_j \\ \infty & \text{otherwise} \end{cases} \qquad \forall\, j \in J \qquad (17)$$

and $b_j' = b_j / a_{ij}$

Note that the entry in V which is not an ∞ corresponds to a y_{ij} in the constraints (16). Let $v_j^* = \min\{v_{ij} : i \in I_j\}$, $\forall j \in J$ be the minimum value in column j. Let f_j denote the least $i \in I_j$ such that $v_j^* = v_{f_j j}$.Consider the following m feasible solutions defined as : for each i = 1,2,....., m, y_{ij} = 1 for $j \in J_i$ and $y_{f_j j} = 1$ for $j \notin J_i$.

Assume that there are k_i distinct f_j for all $j \notin J_i$, denoted by

$$t_1^i, \ldots\ldots, t_{k_i}^i .$$

Let $G_s^i = \{ j \notin J_i. : f_j = t_s^i \}$ for all s = 1,2,....., k_i. Let g_s^i denote the largest element in G_s^i.

The objective value Z_i, yielded by the i^{th} feasible solution is computed by

$$Z_i = \max_{j \in J_i} \{ c_i' b_j' \} + c'_{t_1^i} \hat{x}_{g_1^i} + \ldots + c'_{t_{k_i}^i} \hat{x}_{g_{k_i}^i} \quad (18)$$

The initial upper bound $\tilde{Z}$ for the sub-problem is

$$\tilde{Z} = \min_{i \in I} \{ Z_i \}.$$

With the initial upper bound, we will employ the backward branch-and-bound method with jump-tracking technique to solve the 0-1 integer programming problem (18). The 'backward' is employed to indicate that the b and b starts from the last column and towards to first column. The reason for adopting backward direction is to anticipate the "branches" in the solution tree are likely to be fathomed by the incumbent upper bound because of the increasing structure in c and b.

Assume that $y_{i_1 j_1} = 1$, $y_{i_2 j_2} = 1$,...., $y_{i_n j_n} = 1$ is an optimal solution for the 0-1 integer programming problem. Suppose that there are s distinct elements in $\{i_1, .., i_n\}$,denoted by $\{i_1^*, \ldots\ldots, i_s^*\}$. Let

$$j_k^* = \max \{ j_t | \, y_{i_k^*, j_t} = 1 \} \text{ for } k = 1, 2, \ldots\ldots, s.$$

Then, an optimal solution for (12) is given by $x^* = (x_i^*)$

where

$$x^*_{i_k} = b'_{j_k} \quad \text{for all } k = 1,\ldots, s.$$

and $x^*_i = 0$ for all $i \notin \{i^*_1,.....,i^*_s\}$.

Now, we will present step-by-step algorithm which computes the optimal solution.

5. Algorithm

Step 1 : Rename the variables and arrange the order of fuzzy relation equation so that the coefficients in c and b are increasing respectively.

Step 2 : Find the maximum solution of system (1).

Compute $\hat{x} = A@b=[\bigwedge_{j=1}^{n}(a_{ij} @ b_j]_{i\in I}$ according to (4).

Step 3: Check feasibility.

If $\hat{x}\, oA = b$, continue. Otherwise, stop! And problem (3) has no feasible solution.

Step 4 : Decompose the problem according to (10) and (11).

Step 5 : Solve the sup-problem (11) using lemma 5.

Compute $Z'' = \sum_{i=1}^{m} c''_i \hat{x}_i \quad , c'' \le 0_i$

Step 6 : Upper bound technique for sub-problem (10).

(i) Compute index sets I_j for all $j \in J$ and J_i for all $i \in I$.

(ii) (optional) Use remark to compute the value of variables x_i and Z'_i for all $i \in \bar{I}$.

(iii) Generate the associated 0-1 integer programming problem to (10).

(iv) Generate the basis matrix V. Descard the rows and columns diagnosed in (ii) .

(v) Compute the initial upper bound $\breve{Z}$.

(vi) Employ the backward branch-and-bound method with jump-tracking technique to solve for 0-1 integer programming problem.

(vii) Generate the optimal solution for the problem (10) from (ii) and (vi).

Compute $\breve{Z}^* = \breve{Z} + \sum Z'_i \quad , \quad i \in \bar{I}$

Step 7: Generate an optimal solution.

Compute the optimal solution of (3) from step 5, step 6(vii) via formulae (14) and (15). Compute $Z^* = \breve{Z}^* + Z''$.

Example :

Solving problem (3) with c = (-4, 3, 2, 3, 5, 2, 1, 2,5 , 6),

b = (0.48, 0.56, 0.72, 0.56, 0.64, 0.72, 0.42, 0.64), and

A=

$$\begin{bmatrix} 0.6 & 0.2 & 0.5 & 0.3 & 0.7 & 0.5 & 0.2 & 0.8 \\ 0.5 & 0.6 & 0.9 & 0.5 & 0.8 & 0.9 & 0.3 & 0.8 \\ 0.1 & 0.9 & 0.4 & 0.7 & 0.5 & 0.7 & 0.4 & 0.7 \\ 0.1 & 0.6 & 0.2 & 0.5 & 0.4 & 0.1 & 0.7 & 0.5 \\ 0.3 & 0.8 & 0.8 & 0.8 & 0.8 & 0.5 & 0.5 & 0.8 \\ 0.8 & 0.4 & 0.1 & 0.1 & 0.2 & 0.8 & 0.8 & 0.3 \\ 0.4 & 0.5 & 0.4 & 0.8 & 0.4 & 0.7 & 0.3 & 0.4 \\ 0.6 & 0.3 & 0.4 & 0.3 & 0.1 & 0.2 & 0.5 & 0.7 \\ 0.2 & 0.5 & 0.7 & 0.4 & 0.9 & 0.9 & 0.7 & 0.2 \\ 0.1 & 0,3 & 0.6 & 0.6 & 0.6 & 0.4 & 0.4 & 0.8 \end{bmatrix}$$

The objective function is

$$Z = -4x_1+3x_2+2x_3+3x_4+5x_5+2x_6 +x_7+2x_8+5x_9+6x_{10}$$

Step 1 : The rearranged structure is

$$W = 0y_1+y_2+2y_3+2y_4+2y_5+ 3y_6+3y_7+5y_8+5y_9+6y_{10}$$

$c=(0,1,2,2,2,3,3,5,5,6)$,

$b=(0.42,0.48,0.56,0.56,0.64,0.64,0.72,0.72)$

$$A = \begin{bmatrix} 0.2 & 0.6 & 0.2 & 0.3 & 0.7 & 0.8 & 0.5 & 0.5 \\ 0.3 & 0.4 & 0.5 & 0.8 & 0.4 & 0.4 & 0.4 & 0.7 \\ 0.4 & 0.1 & 0.9 & 0.7 & 0.5 & 0.7 & 0.4 & 0.7 \\ 0.8 & 0.8 & 0.4 & 0.1 & 0.2 & 0.3 & 0.1 & 0.8 \\ 0.5 & 0.6 & 0.3 & 0.3 & 0.1 & 0.4 & 0.4 & 0.2 \\ 0.3 & 0.5 & 0.6 & 0.5 & 0.8 & 0.8 & 0.9 & 0.9 \\ 0.7 & 0.1 & 0.6 & 0.5 & 0.4 & 0.5 & 0.2 & 0.1 \\ 0.5 & 0.3 & 0.8 & 0.8 & 0.8 & 0.8 & 0.8 & 0.5 \\ 0.7 & 0.2 & 0.5 & 0.4 & 0.9 & 0.2 & 0.7 & 0.9 \\ 0.4 & 0.1 & 0.3 & 0.6 & 0.6 & 0.8 & 0.6 & 0.4 \end{bmatrix}$$

Step 2 : $\hat{y}$ = (0.8, 0.7, 0.622, 0.525, 0.8, 0.8, 0.6, 0.7, 0.6, 0.8)

Step 3 : Solution is feasible.

Step 4 : c'=(0,1,2,2,2,3,3,5,5,6),

c''=(-4,0,0,0,0,0,0,0,0,0).

Step 5 : $y_1^* = 0.8$ and $Z'' = -3.2$.

Step 6 : (*i*) I_1= {4,7,9}, I_2 ={1,5}, I_3 = {3,8}, I_4 ={2,8}, I_5 = {6}, I_6 = {1,6,10},

I_7 = {6}, I_8 = {6}.

J_1 = {2,6}, J_2 = {4}, J_3 = {3,8}, J_4 = {1}, J_5 = {2}, J_6 = {5,6,7,8}, J_7 = {1}, J_8 = {3,4}, J_9 = {1}, J_{10} = {6}.

(ii) *Problem reduction.*

$\bar{I}$ = {6}, J_6 = {5, 6, 7, 8}, $\bar{J}$ = {5, 6, 7, 8} and $y_6^* = \hat{y}_6 = b_6' = 0.8$, $\bar{Z} = 2.4$

$\dot{I}$= {1,2,3,4,5,7,8,9,10} and $\dot{J}$ = {1,2,3,4}.

$\Lambda' = I_1 \times I_2 \times I_3 \times I_4$. $|\Lambda'| = 24$, while $|\Lambda| = 72$.

(iii) Associated 0-1 integer programming problem is

$$\min Z = \max\{0.7\, y_{24}\} + \max\{1.244\, y_{33}\} + \max\{1.05\, y_{41}\} + \max\{1.6\, y_{52}\} + \max\{1.8\, y_{71}\} + \max\{3.5\, y_{83} + 3.5\, y_{84}\} + \max\{3.0\, y_{91}\}$$

s.t.

$$y_{41} + y_{71} + y_{91} = 1$$

$$y_{12} + y_{52} = 1$$

$$y_{33} + y_{83} = 1$$

$$y_{24} + y_{84} = 1$$

$y_{ij} = 0$ or 1 for $i \in I_j, j \in J'$

(iv) Basis matrix V is

$V=$

$$\begin{bmatrix} \infty & 0.0 & \infty & \infty & \infty & 0.0 & \infty & \infty \\ \infty & \infty & \infty & 0.7 & \infty & \infty & \infty & \infty \\ \infty & \infty & 1.244 & \infty & \infty & \infty & \infty & \infty \\ 1.050 & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\ \infty & 1.600 & \infty & \infty & \infty & \infty & \infty & \infty \\ \infty & \infty & \infty & \infty & 2.4000 & 2.4000 & 2.4000 & 2.4000 \\ 1.800 & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\ \infty & \infty & 3.500 & 3.500 & \infty & \infty & \infty & \infty \\ 3.000 & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\ \infty & \infty & \infty & \infty & \infty & 4.800 & \infty & \infty \end{bmatrix}$$

The v_j^* and f_j for all $j \in J$ are presented as (v_j^*, f_j).

$(v_1^* = 1.050, f_1 = 4), (v_2^* = 0.0, f_2 = 1),$
$(v_3^* = 1.244, f_3 = 3), (v_4^* = 0.7, f_4 = 2),$
$(v_5^* = 2.4, f_5 = 6), (v_6^* = 0.0, f_6 = 1),$
$(v_7^* = 2.4, f_7 = 6), (v_8^* = 2.4, f_8 = 6)$

The basis matrix for reduced problem is

$V =$

$$\begin{bmatrix} \infty & 0.0 & \infty & \infty \\ \infty & \infty & \infty & 0.7 \\ \infty & \infty & 1.244 & \infty \\ 1.05 & \infty & \infty & \infty \\ \infty & 1.6 & \infty & \infty \\ 1.8 & \infty & \infty & \infty \\ \infty & \infty & 3.5 & 3.5 \\ 3.0 & \infty & \infty & \infty \end{bmatrix}$$

The v_j^* and f_j for all $j \in J'$ are presented as (v_j^*, f_j).

$(v_1^* = 1.050, f_1 = 4), (v_2^* = 0.0, f_2 = 1),$
$(v_3^* = 1.244, f_3 = 3), (v_4^* = 0.7, f_4 = 2)$

(v) Generate an initial upper bound.

First we compute, Z_i , $i \in I'$.

$Z_1 = 0 + 1.05 + 1.244 + 0.7 = 2.994$

$Z_2 = 0.7+0 +1.05+1.244 =2.994$

$Z_3 = 1.244+ 1.05+ 0 +0.7 =2.994$

$Z_4 = 1.05+ 0 + 1.244+0.7 = 2.994$

$Z_5 =1.6 + 1.05+1.244+0.7 = 4.594$

$Z_7 = 1.8+0 +1.244+0.7 = 3.744$

$Z_8 = 3.5+1.05+0 = 4.55$

$Z_9 = 3.0+0+1.244+0.7 =4.244$

Then, the initial upper bound for the reduced sub-problem is

$\breve{Z}$=min (2.994, 2.994, 2.994, 2.994, 4.594, 3.744, 4.55, 4.244) = 2.994

The feasible solution that yielded the initial upper bound (for all four cases) is

$$y_{12} = y_{24} = y_{33} = y_{41} = 1.$$

(vi) The backward jump-tracking branch-and-bound approach.

To ensure the 'backward' branch-and bound, we start from the last column and move towards the first column. Fig. 1 shows the solution tree generated by this *b* and *b* approach. From the last column, we have I_4= {2,8}.This implies either y_{24}=1 or

y_{84}=1. This yields two branches from the start node in Fig. 1. Moving to node 1 means that we set y_{24}=1 (and, hence y_{84}=0). In node 1, we have Z'= 0.7. On the other hand, if we move along y_{84}=1 to node 2, we have Z'=3.5 in node 2. Z' in node 1 is less than the initial upper bound, so we proceed branching at node 1. Z' at node 2 is more than the initial upper bound so we stop branching at this node. Since I_3 = {3,8} implies that either y_{33} = 1 or y_{83}=1. Branching from node 1 along y_{33} and y_{83} yields node 3 and node 4 in Fig. 1, respectively. Updating Z'at node 3 and node 4 yields Z'=1.944 at node 3 and Z'=4.2 at node 4. Since Z' at node 4

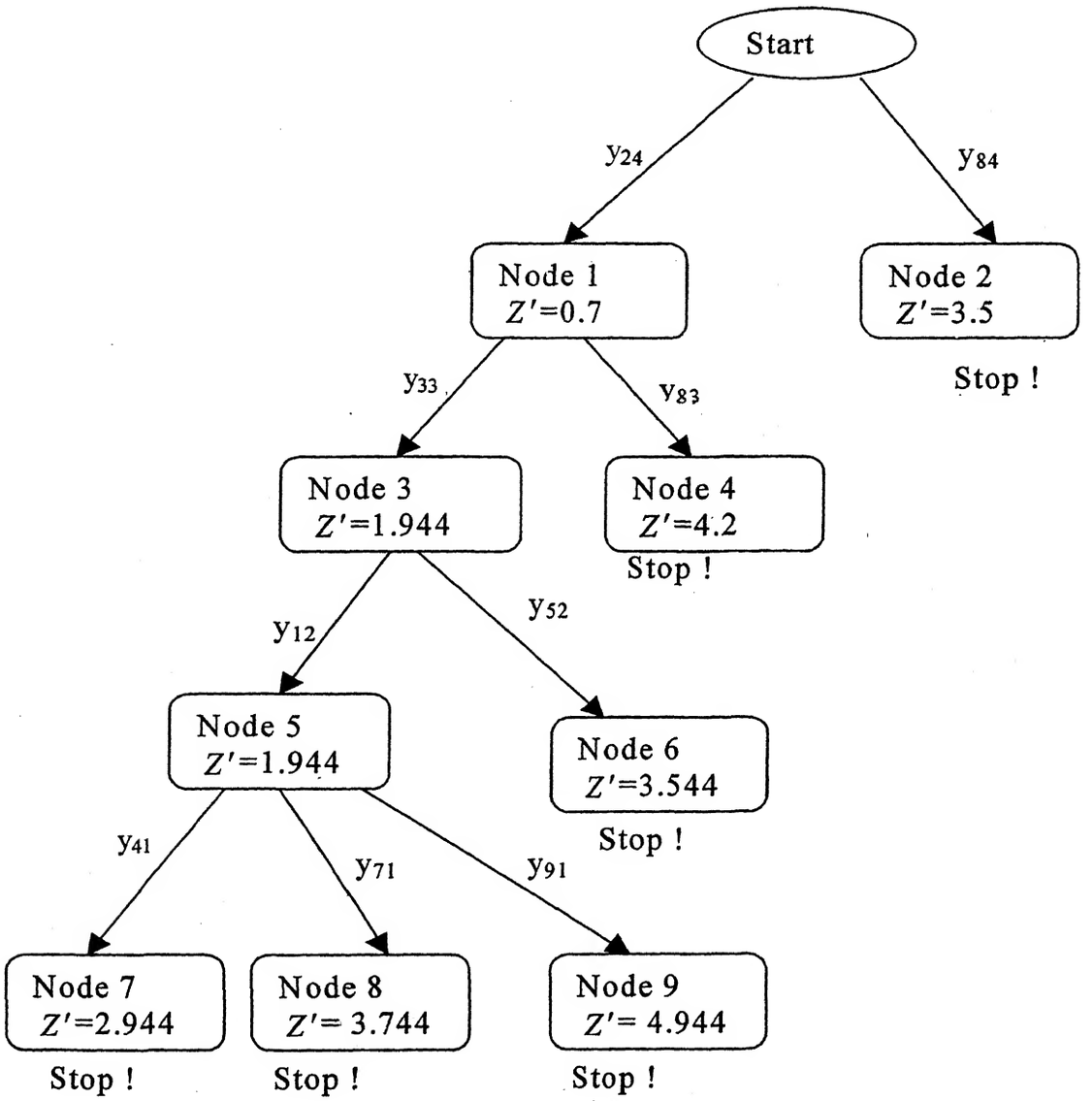

Fig. 1– Backward branch-and-bound method

exceeds the initial upper bound, branching at node 4 is dismissed. We proceed branching at node 3. Since I_2= {1,5}, branching at node 3 along y_{12}=1 and y_{52}=1 generates node 5 and node 6, respectively. Updated Z' at node 5 and node 6 shows that Z' at node 6 is dismissed. Since I_1= {4,7,9}, branching at node 5 along y_{41}=1, y_{71} =1 and y_{91}=1 yields node 7, node 8 and node 9, respectively. Updating Z' at these nodes, we have Z'=2.994 at node 7, Z'=3.744 at node 8 and Z'=4.944 at node 9. Z' at node 7 is equal to initial upper bound 2.994, node 7 is fathomed. In Fig. 1, nodes 7,8,9, 6,4,2 are the terminating leaves in the solution tree. This shows that the initial upper bound is indeed the optimal solution for our sub-problem. Any feasible solution that generates the upper bound is an optimal solution. In this case, we select y_{41}= y_{12} = y_{33} = y_{24} = 1 to be an optimal solution for the 0-1 integer programming problem.

(vii) Generating optimal solution for the sub-problem (10) with positive costs :

y^*=(0.8,0.7,0.622,0.525,0.0,0.8,0.0, 0.0,0.0,0.0)

and

$$\breve{Z}^* = \bar{Z} + \breve{Z} = 2.4 + 2.994 = 5.394.$$

Step 7 : Generating optimal solution for the original problem:

x^*= (0.8, 0.8, 0.622, 0.0, 0.0, 0.525, 0.7, 0.0, 0.0, 0.0)

and

$$Z^* = \breve{Z}^* + Z'' = 5.394 - 3.2 = 2.194$$

Conclusions

In this communication, we have studied a linear optimization problem subject to a system of fuzzy relation equations with max-product composition. The optimization problem is decomposed into two sub-problems; one with non-negative cost coefficients and other with negative cost coefficients. The maximal element of the feasible domain is the optimal solution of sub-problem with negative costs. The sub-problem with non-negative costs is rearranged in increasing c and b. The upper bound for optimal objective value is computed. The problem is transformed into equivalent 0-1 integer programming problem and solved by using backward jump-tracking branch-and-bound scheme. If problem size is large, the basis matrix is certainly large. We take the advantage of the structure of the feasible domain and reduce the size of the matrix so that the effort required to solve it is minimized.

Performance of our algorithm can be compared with the algorithm given in literature[9,11,18]. According to literature[18] complexity, for the example in Section 5, is 72, while in our case it is 24. This can further be reduced if we go through literature[11,12]

It may be possible to use this procedure by generating basis matrix for the optimization problem with mixed (negative and positive) costs.

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Fuzzy matrix *m*–ordering

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Abstract

The purpose of this paper is to introduce *m*-ordering in fuzzy square matrices and some properties of fuzzy matrix *m*-ordering.

(Keywords : Fuzzy matrix/m-norm/partial ordering/*m*-ordering/ *m*-superior/ *m*-inferior/ outer and inner inverses)

Introduction

The concept of fuzzy set was introduced by Zadeh[1] in 1965. Kim and Roush[2] developed the notion of various inverses of fuzzy matrices. Further study on fuzzy matrices was done by Hanhyuk Cho[3] and he analysed the generalized inverses of fuzzy regular matrices. Outer and inner inverses of fuzzy matrices and T-ordering in fuzzy matrices were introduced by Jianmiao Cen[4]. Mainly based on Jianmiao Cen[4] in this paper we introduce *m*-norm on fuzzy matrices which leads to get various partitions of $M_n(F)$ and *m*-ordering in $M_n(F)$ and some of their properties are discussed.

We shall consider F the fuzzy algebra [0,1] with operations (+, .) and the standard order "≤" where $a + b = \max\{a, b\}$, $a.b = \min\{a, b\}$ for all $a, b \in F.F$ is a commutative semiring with additive and multiplicative identities 0 and 1 respectively. Let $M_n(F)$ denote the set of all fuzzy matrices of order n. Define "+" and scalar multiplication in $M_n(F)$ as $A+B = [a_{ij} + b_{ij}]$ where $A=[a_{ij}]$, $B=[b_{ij}]$ and $cA=[ca_{ij}]$ where $c \in [0, 1]$. Thus $M_n(F)$ forms a vector space.

Fuzzy *m*-Norm and Partitions of $M_n(F)$

To analyse more properties of $M_n(F)$ we introduce the concept of norm in $M_n(F)$ and thus we have defined for every A in $M_n(F)$ a non-negative quantity say m-norm is defined in the following way.

Definition 1: For every A in $M_n(F)$ the *m*-norm of A is defined as

$$\|A\|_m = \max [a_{ij}] \text{ where } A = [a_{ij}]$$

or

$$= \sum_{j=1}^{n} \sum_{i=1}^{n} a_{ij}$$

Definition 2: For all A in $M_n(F)$ define

$A\{1\} = \{x \in M_n(F) / ||x||_m > ||A||_m \}$

$A\{2\} = \{x \in M_n(F) / ||x||_m < ||A||_m \}$

$A\{3\} = \{x \in M_n(F) / ||x||_m = ||A||_m \}$

$A\{4\} = \{x \in M_n(F) / AXA = A\}$

$A\{5\} = \{x \in M_n(F) / XAX = X\}$

Clearly $M_n(F) = A\{1\} \cup A\{2\} \cup A\{3\}$

The set $A\{1\}$is called as m-superior to A and $A\{2\}$ m-inferior to A. Clearly $A\{3\}$ is m-equivalent to A. $A\{4\}$ and $A\{5\}$ are known as the sets of inner and outer inverses of A.

Theorem 1: For each A in $M_n(F)$ the following results are true.

(i) If $X \in A\{i\}$ then X^T is also in $A\{i\}$ for i =1,2,3 where X^T is the transpose of X.

(ii) If $A_1 \in A\{1\}$, $A_2 \in A\{2\}$, $A_3 \in A\{3\}$ then $||A_1 + A_2 + A_3||_m = ||A_1||_m$

(iii) $||A_1A_2A_3||_m = ||A_2||_m$

(iv) $A^T \in A\{3\}$ for all A in $M_n(F)$

Proof:

(i) $||X||_m = ||X^T||_m$ since $||X||_m = \max [a_{ij}]$

(ii) $||A_1||_m > ||A||_m$, $||A_2||_m < ||A||_m$, $||A_3||_m = ||A||_m$

Therefore $||A_1 + A_2 + A_3||_m =$

$$|| A_1 ||_m + || A_2 ||_m + || A_3 ||_m = ||A_1||_m$$

(iii) $||A_1A_2A_3||_m =$

$$||A_1||_m ||A_2||_m ||A_3||_m = ||A_2||_m$$

(iv) $||A||_m = ||A^T||_m$.

Therefore for all $A \in M_n(F)$, $A^T \in A\{3\}$

Theorem 2 :

(i) For all $X \in A\{4\}$, $||A||_m \leq ||X||_m$

(ii) For all X in $A\{5\}$, $||X||_m \leq ||A||_m$

Further for all X in $A\{4\} \cap A\{5\}$ the matrices AX and XA are idempotent.

Proof: If $X \in A\{4\}$ then $AXA = A$.

Therefore

$$||AXA||_m = ||A||_m \Rightarrow ||A||_m ||X||_m ||A||_m = ||A||_m$$

$$\Rightarrow ||A||_m \leq ||X||_m$$

(i)If $X \in A\{5\}$then $XAX = X$.

Therefore $||XAX||_m =$

$$||X||_m \Rightarrow ||X||_m \leq ||A||_m$$

(ii)If $X \in A\{4\} \cap A\{5\}$

then $AXA = A$ (1)

and $XAX = X$ (2)

$XAXA = XA \Rightarrow (XA)^2 = XA$, from (1)

Similarly from (2), $(AX)^2 = AX$. Therefore XA and AX are idempotent.

Properties of *m*-Ordering

Definition 3 : The m-ordering $A \overset{m}{\leq} B$ in $M_n(F)$ is defined as

$A \overset{m}{\leq} B \Leftrightarrow ||A||_m \leq ||B||_m$

Theorem 3 : The m-ordering is not a partial ordering

Proof : Clearly $||A||_m \leq ||A||_m \ \forall$ $A \in M_n(F)$ Hence $A \overset{m}{\leq} A$.

Therefore reflexivity is true.

$A \overset{m}{\leq} B \Rightarrow ||A||_m \leq ||B||_m$

$B \overset{m}{\leq} A \Rightarrow ||B||_m \leq ||A||_m$

$A \overset{m}{\leq} B$ and $B \overset{m}{\leq} A \Rightarrow ||A||_m = ||B||_m$.

But $||A||_m = ||B||_m$ does not imply $A = B$

Therefore anti symmetry is not true.

$A \overset{m}{\leq} B$, $B \overset{m}{\leq} C \Rightarrow A \overset{m}{\leq} C$, $\forall$ A, B, C in $M_n(F)$

For $||A||_m \leq ||B||_m$, $||B||_m \leq ||C||_m \Rightarrow ||A||_m \leq ||C||_m$

Therefore transitivity is true.

Thus the m-ordering is not a partial ordering in $M_n(F)$

Theorem 4: If $A \overset{m}{\leq} B$ then

(i) $A^T \overset{m}{\leq} B^T$

(ii) $AB^T \overset{m}{\leq} BB^T$, $B^TA \overset{m}{\leq} B^TB$

(iii) $A^TA \overset{m}{\leq} B^TB$, $AA^T \overset{m}{\leq} BB^T$

$A^n \overset{m}{\leq} B^n$ for any positive integer n.

Proof: (i) $||A||_m = ||A^T||_m$, $||B||_m = ||B^T||_m$

Therefore $||A||_m \leq ||B||_m \Rightarrow ||A^T||_m \leq ||B^T||_m$

ie., $A \overset{m}{\leq} B \Rightarrow A^T \overset{m}{\leq} B^T$

(ii) $||AB^T||_m \leq ||A||_m \, ||B^T||_m = ||A||_m \, ||B||_m$
$= ||A||$ Since $A \overset{m}{\leq} B$

$||BB^T||_m = ||B||_m \, ||B^T||_m = ||B||_m \, ||B||_m$
$= ||B||_m$

$A \overset{m}{\leq} B \Rightarrow ||A||_m \leq ||B||_m \Rightarrow ||AB^T||_m$
$\leq ||BB^T||_m$

Therefore $A \overset{m}{\leq} B \Rightarrow AB^T \overset{m}{\leq} BB^T$

Similarly $A \overset{m}{\leq} B \Rightarrow B^TA \overset{m}{\leq} B^TB$

(iii) $||A^TA||_m = ||A^T||_m ||A||_m = ||A||_m ||A||_m$
$= ||A||_m$

$||B^TB||_m = ||B^T||_m ||B||_m = ||B||_m ||B||_m = ||B||_m$

$A \overset{m}{\leq} B \Rightarrow ||A||_m \leq ||B||_m \Rightarrow ||A^TA||_m$
$\leq ||B^TB||_m$

$\Rightarrow A^TA \overset{m}{\leq} B^TB$

Similarly $A \overset{m}{\leq} B \Rightarrow AA^T \overset{m}{\leq} BB^T$

(iv) $||A^n|| = ||A..... \ n \text{ times}||_m = ||A||_m$

$||A||_m ..... \ n \text{ times} = ||A||_m$

$||B^n|| = ||B..... \ n \text{ times}||_m = ||B||_m$

$||B||_m ..... \ n \text{ times} = ||B||_m$

$A \overset{m}{\leq} B \Rightarrow ||A||_m \leq ||B||_m \Rightarrow ||A^n||_m \leq ||B^n||_m$

$\Rightarrow A^n \overset{m}{\leq} B^n$ for any positive integer n.

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A Report on Science Communication Activities undertaken by the Academy on the eve of National Science Day

The National Academy of Sciences, India has been organizing science communication activities for the last several years to stimulate the students for cultivation of scientific temperament and to opt science as a career. It organizes science quiz, debate, oration, exhibition, essay, creative writing and painting contests as well as the workshop for the teachers.

Extension Lectures

Under the **Science Extension Lectures**, the Academy organized many lectures in Allahabad. Prof. Govindjee, Emeritus Scientist, University of Illinois, Urbana, U.S.A. delivered a talk to an audience of more than 200 on 'Pioneers of Photo-synthesis' in the Botany Department, Allahabad University on January 27, 2004.

Dr. R.K. Srivastava of Motilal Nehru National Institute of Technology (MNNIT) delivered a very informative and conceptual lecture on "Basics of Computer & Its Scope" in Prayag Mahila Vidyapeeth Inter College, Allahabad on February 20, 2004.

On February 21, Prof. S.L. Srivastava delivered an illustrative lecture on "Remote Sensing" in Army School, Allahabad. The lecture was attended by a large number of students and teachers. On the same day another lecture was delivered by Dr. (Mrs.) Ragini Mehrotra of Motilal Nehru Medical College, Allahabad in Maharishi Patanjali Vidyamandir (MPVM) on a very interesting topic – "AIDS" which was liked and appreciated by both students and teachers.

On February 23, two more extension lectures were organized in two different institutions. Dr. Pankaj Srivastava, MNNIT delivered a descriptive lecture on "History, Scope & Application of Mathematics" in Kendriya Vidyalaya, Old Cantt., Allahabad. Another lecture on Neuroreceptors was delivered by Prof. U.C. Srivastava of Zoology Department, Allahabad University (A.U.) in Umrao Singh Memorial Girls Inter College (USMGIC), Allahabad.

Prof. (Ms.) Dipika Kaul delivered a conceptual and illustrative lecture on "Genes" on February 28, in Jamuna Christian Inter College (JCIC), Allahabad. Over more than 150 students attended the lecture.

Science Week Programmes

A **"Science Creative Writing & Painting Contest"** was organized for the first time on February 21 in the Academy and more than 70 students of Allahabad Schools participated in this contest. The topics were – (1) Computer Age and (2) Advancing Pollution. The students were asked to extrapolate and imagine about the futuristic effects of increasing use of computer in each and every aspect of life and also the trend of increasing pollution and its effect on the earth planet. The Judges were Dr. Anita Gopesh, Zoology

Department, A.U. and Dr. Rajeev Srivastava. MNNIT. Finally 4 students were selected – two for writing and another two for drawing the sketch on these themes. They were Supriya Verma, MPVM and Shashank Kumar, St. Joseph for Writing and Aparna Singh, MPVM and Gunjan Gautam, MPVM for Drawing.

State Level Contests - On the eve of National Science Day (February 28, 2004) State Level Contests were also organized by the Academy from February 24-28, 2004. To select the participants from the districts of Uttar Pradesh, the responsibility was given to the District Inspector of Schools of every district through the Additional Director (Sri Mitra Lal), Secondary Education, Government of Uttar Pradesh and the Academy received the names of the student participants from around 32 districts of U.P. The students started reaching Allahabad from the evening of February 23 to participate in State Level Science Quiz held on February 24, Debate held on February 25, Oration held on February 26, Essay Writing competition held on February 26, Exhibition held on February 27-28. Around 240 students participated in all these contests and 60 teachers attended the State Level Teachers Workshop.

On February 24, **the inauguration of all these programmes** were held at 10.00 a.m. in the Auditorium of the new building of the Academy at 5, Lajpatrai Road, Allahabad. Two minutes silence was observed in the memory of Late Prof. H.C. Khare, who had breathed his last on February 7, 2004. Prof. S.L. Srivastava, Formerly Head, Physics Department, A.U. and the Coordinator of Science Communication Programmes of the Academy, welcomed the Guests, Fellows, Members, Teachers, Scientists and outstation participants on this occasion and gave a brief account of the various activities undertaken by the Academy. Prof. B.B.L. Saxena, Senior Fellow of the Academy has very kindly accepted to be the Chief Guest on this occasion and Prof. Chandrika Prasad, a very Senior Fellow of the Academy, presided over the function. Prof. Sheo Gopal Misra, General Secretary, Vigyan Parishad, Allahabad and Prof. C.B.L. Srivastava, Formerly Head, Zoology Department, A.U. were the Guests of Honour. Prof. B.B.L. Saxena appealed to the students to participate in the science communication activities so that a scientific and rational approach be generated in the society and the students become responsible citizens of the future. Prof. U.C. Srivastava presented the plan of next five days in which various science communication activities were to be undertaken. Dr. M.S. Sinha, Executive Secretary of the Academy, proposed a vote of thanks.

After the inauguration, the **State Level Quiz** was organized from 12.00 noon. Dr. (Mrs.) Sharda Sundaram of Chemistry Department, Ewing Christian College, Dr. Pankaj Srivastava of MNNIT, Dr. Ravindra Dhar of Physics Deptt., ECC, Prof. U.C. Srivastava of Zoology Deptt., A.U. and Prof. D.K. Chauhan of Botany Deptt., A.U. acted as the experts to conduct the quiz. The students of 26 districts of U.P. participated in this event and after a very tough contest Allahabad team was declared the winner, while J.P. Nagar team as runner-up. The winners were (a) Piyush Srivastava, (b) Ankit Agarwal, (c) Dipendra Kumar Shukla from Allahabad and runners up were (a) Vikas Agrawal, (b) Rohit Kumar Yadav, (c) Amit Deol from J.P. Nagar. Prof. S.L. Srivastava thanked the

Judges and accepted that the standard of the contestants in quiz this year was remarkably high.

On February 25, **State Level Debate Contest** was held on the topic : 'Should India Send a Mission to Moon', in which students from 30 districts participated. After a keen contest Ms Amrita Singh of D.P. Girls Inter College, Allahabad was the first winner, while Ms. Pragya Tiwari of Gazipur and Ms. Swati Tiwari of Balia jointly stood second. Dr. R.K. Srivastava, Prof. S.C. Prasad, Dr. S.S. Narvi and Dr. Rajeev of MNNIT very kindly acted as Judges.

State Level Essay Contest for Undergraduate students was held on February 26, 2004. The topic of Essay was "Future Energy Sources" and Judge for this event was Prof. (Ms.) D. Kaul. The winner was Ms. Alka Sachan from Hamirpur.

On February 27, the students went for site seeing from 9.00 a.m. to 5.00 p.m. Sri Milan Das escorted them. They enjoyed the short trip to various historical places in and around Allahabad. In the evening of the same day they presented a colourful cultural programme for the teachers and resource persons, for which they were thanked by Prof. S.L. Srivastava.

The **State Level Exhibition** was held on February 28, 2004. Prof. C.B.L. Srivastava, Prof. Abhai Mansingh, Prof. U.C. Srivastava, Dr. Anita Gopesh and Dr. (Mrs.) Sasmita Mohanty very kindly judged the exhibits. The winners of Exhibition were : Working Model – I. Ankit and Jayant of Ballia, II. Ashutosh Singh of Faizabad. Non-working Model – I. Rakesh Kumar Singh of Ghaziabad, II. Km. Ayushi Saxena of Badaun, Chart – I. Km. Anamika Vashishtha of Agra, II. Sudeep Jaiswal of Bahriach

Teacher's Workshop : The State Level Teacher's Workshop was held from Feb. 25-27, 2004. More than 60 teachers from the intermediate colleges of U.P. participated in the workshop. Teachers of biological sciences stream visited Zoology Department, A.U. on Feb. 25, 04, where the workshop was conducted by Prof. U.C. Srivastava and lectures were delivered by Prof. C.B.L. Srivastava, Prof. (Ms) D. Kaul, Prof. Pratima Gaur, Prof. U.C. Srivastava and Dr. Anita Gopesh. Dr. R.R. Tiwari demonstrated many live experiments to the participants.

On 26th February the workshop for physical science teachers was held in the council room of the Academy, where Dr. Pankaj Srivastava, and Dr. S.N. Singh MNNIT, delivered talks on "Application of Mathematics in Information Science" and "Ramanujan's contributions in the field of Mathematics" respectively. In the afternoon these teachers visited laboratories of MNNIT and active discussion was initiated on the need of proper laboratory training at 10+2 level by the resource persons Dr. Ramesh Tripathi and Dr. Anirudh Narayan of Department of Electrical Engineering. Later on they demonstrated various experiments of basic electrical engineering. The teachers visited the Super Computer Laboratory where Er. A.K. Singh of Department of Computer Science and his students explained the working of super computer.

Prof. U.C. Srivastava delivered a talk on 'Endocrine and Neuronal Coordination' from 1.30 to 3.00 p.m. which was appreciated by all teachers of biological stream and the students.

In the morning of 27th February, biological science teachers visited Central Inland Fisheries Research Institute and physical science teachers MNNIT where Dr. B.P. Mohanty and Dr. R.K. Srivastava conducted the workshops, respectively.

In the afternoon, Prof. Abhai Mansingh, Formerly Professor of Physics, Delhi University and Director, South Campus, New Delhi addressed the teachers of physical sciences stream and deliberated on the improvement of laboratories at 10+2 level. He proposed that a Science Centre be established in each district of U.P. Prof. S.L. Srivastava described the progress made on Smart Materials in the global scenario. He emphasized the need of proper science education so that Indian Science does not lag behind.

National Science Day Programme

The **National Science Day Function** was organized jointly with Harish-Chandra Research Institute (HRI) at 3.30 p.m. on 28th February, 04 in the Auditorium of the Academy at Allahabad. Prof. Krishna Kumar, Director, MNNIT was the Chief Guest and Prof. Ravi. S. Kulkarni, Director, Harish-Chandra Research Institute, Prof. Abhai Mansingh and Prof. Chandrika Prasad were the Guests of Honour.

Prof. S.L. Srivastava welcomed the guests and participants and gave a detailed account of all the activities undertaken by the Academy on the eve of National Science Day.

Prof. Chandrika Prasad distributed the prizes and certificates to the winners of all the above contests. The National Academy of Sciences, India - Science Teacher Award was given to Dr. Narain Sharan of Government Inter College, Meerut by Prof. Krishna Kumar. Dr. Narain Sharan is a postgraduate in Science and Education; and he also obtained his Ph.D. degree in Education. The students of his college have bagged many prizes at district and state level under his guidance.

Prof. R.S. Kulkarni described the programme held at HRI and gave the prizes to the winners of 'Talent Search Examination 2003' held at HRI during November 2003. He told the gathering that the National Science Day is celebrated as the Raman effect day, for which Dr. C.V. Raman was awarded Nobel Prize in 1930. The list of prize winners of the programme held at HRI is given below :

In Mathematics Group (Level I – Class IX and X) Mr. Abhishek Srivastava of MPVM stood first and Mr. Prashant Jain of MPVM stood second. In Physics Group (Level I – Class IX and X) Mr. Pulkit Anand of St. Joseph's College stood first , Mr. Vivek Gauri of Boys High School (BHS) stood second and Mr. Vishal Kesarwani of BHS and Mr. Aditya Kumar Singh of St.Joseph's College jointly stood third.

In Mathematics Group (Level II – Class XI and XII) Mr. Saaransh Gulati of BHS and Mr. Devvrat Tripathi of MPVM jointly stood first while Mr. Akhilesh Pratap Singh of MPVM stood second. In Physics Group (Level II – Class XI and XII) Mr. Piyush Srivastava of BHS stood first and Mr. Devvrat Tripathi of MPVM stood second.

Chief Guest Prof. Krishna Kumar told that the students should participate in such events regularly and they should not feel discouraged even if they do not win prizes. The participation in these activities is in itself an achievement, because it generates a competitive and scientific temperament.

In an interesting way, he traced the history of science from 10th century to modern era. Indian Science, he observed, was far ahead before 15th century.

Prof. U.C. Srivastava thanked the resource persons, the Executive Secretary (Dr. M.S. Sinha), Assistant Executive Secretary (Dr. Niraj Kumar), Accounts Officer (Sri A.K. Srivastava) and all staff of the Academy for their whole hearted cooperation and untiring efforts to make the programme a success.

Dr. S.P. Misra, Chairman, Local Chapter of the Academy proposed a vote of thanks to the Chief Guest, Guests of Honour, Resource Persons, Guests, Participants, Teachers and the Press for their cooperation.

OBITUARY

Professor Harish Chandra Khare

Professor Harish Chandra Khare General Secretary, The National Academy of Sciences, India, Allahabad and Chairman, Board of Governors, Motilal Nehru National Institute of Technology, Allahabad expired in the after noon of February 7, 2004 at SGPGI, Lucknow after a brief illness.

He was born on October 5, 1927 at Fatehpur (U.P.). After completing his school and college education at the Government High School, Fatehpur and B.N.S.D. College, Kanpur, he joined the University of Allahabad in 1944 and took his B.Sc. and M.Sc. (Mathematics) degrees in 1946 and 1948 respectively. After a short stay as Lecturer in the Ewing Christian College, Allahabad in 1948-49, he joined the Department of Mathematics, University of Allahabad in 1949 as Lecturer. The same year he was selected for the Superior Forest Service but declined the appointment and chose to stay in the University. He went to McGill University, Canada in January 1956 on a fellowship and obtained his Ph.D. degree from that University in 1960. During his stay at McGill University, he served as a Visiting Assistant Professor in the Department of Mathematics. He also started the Computer Centre and lectured on Numerical Analysis and Computer Programming at McGill University. He returned to the University of Allahabad in 1960 and here he was appointed Reader-in-Mathematics in 1964 and Professor of Mathematics in 1976. He was the Dean, Faculty of Science, University of Allahabad during 1985-87. During his service at the University of Allahabad he held many offices. He retired from the University of Allahabad in June 1988.

Professor Khare had been keenly interested in the development of education in the country. He was member of University Grants Commission (UGC) Mathematics Panel and also its Convener. He was appointed Member, University Grants Commission (UGC) by the Government of India in 1984 and served there till 1987. He was associated with the National Commission on Teachers of the Government of India as a Member of its working group.

Professor Khare had been connected with a large number of Universities in various capacities. He had been a Member of the Executive Councils of the Banaras Hindu University, Varanasi, Jawaharlal Nehru University, New Delhi, and the University of Allahabad, Allahabad. He was a Member of the first Executive Council of the newly established Pondichery University. He had been a Member of the following: Council of the Indian Science Congress Association, Executive Committee of Indian Mathematical Society, Establishment Committee of the National Council of Educational Research and Training, New Delhi, Indian Institute of Advanced Study, Simla, Working Group on Higher Education Eighth Five Year Plan, Executive of the All India Council of

Technical Education (AICTE), New Delhi during (1994-97) and Governing Body of the Indian Institute of Tropical Meteorology, Pune.

Professor Khare was appointed, by Government of India, a Member of the Indo-US Sub-Commission on Education and Culture in 1983. He was a Member of UGC delegation to USSR in September 1986 to finalise bilateral agreements in the field of higher education. He as UGC nominee attended International Symposium on Informatics and the Teaching of Mathematics in Developing Countries at Monastir, Tunisia in February 1986. He attended, on behalf of the UGC, the South Asian Regional Workshop of Commonwealth Association of Science, Technology and Mathematics Educators at Singapore in April 1986. He was invited to the Sixth International Congress on Mathematics Education held at Budapest in July/August 1988 to deliver a talk on Mathematics and other subjects. He attended this Congress and also visited other institutions of higher learning and research in Hungary.

Professor Khare was Emeritus Fellow, University Grants Commission and the Coordinator in Mathematics for the preparation of undergraduate Mathematics tele-courses.

Professor Khare had been associated with numerous bodies and committees relating to education in general and mathematics in particular at the national level. He was the Chairman, National Workshop in Vedia Mathematics organiscd by Rashtriya Ved Vidya Pratishthan, at University of Rajasthan, Jaipur on 25-28 March, 1988. He had taken an active part in the restructuring of courses in Mathematics at several Universities.

Professor Khare was the President of Mathematics Section of Indian Science Congress Association in January 1985, and Indian Mathematical Society during 1986-87; He was the General Secretary of Indian Mathematical Society.

Professor Khare was a Fellow of The National Academy of Sciences, India (NASI). Presently he was its General Secretary. He held various offices in the NASI in the past such as Vice-President during 1985-86 General Secretary during 1981-84 and 1989-93; Foreign Secretary during 1987-88; Treasurer during 1996-99: Chief Editor, during (1975-80) and since 1985 and Managing Editor during (1981-84) of the Proceedings of the NASI (Section A - Physical Sciences).

Professor Khare was awarded N.R. Sen Memorial Lecture Award of Calcutta Mathematical Society in 1989; Platinum Jubilee Lecture Award of Indian Science Congress Association in 1991; Distinguished Service Award by Mathematical Association of India in April 1989; P.L. Bhatnagar Memorial Lecture Award of Indian Mathematical Society in 1991.

Suresh Chandra

Emeritus, Scientist,
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Prof. M.P. Tandon

It is always a very painful experience to write an obituary note for a person who was not only a gifted teacher, able guide and distinguished scientist but above all a thorough gentleman. It gives me an opportunity to record my personal regards and gratitude to late Prof. M.P. Tandon.

Prof. Mahesh Prasad Tandon was born on 10th August, 1925 in an extremely wealthy and illustrious family of Allahabad. He had brilliant academic record. After obtaining his B.Sc. and M.Sc. in Ag. Botany degrees from Allahabad University, he joined research under the erudite guidance of Prof R. N. Tandon, an internationally renowned Plant Pathologist. He got his D.Phil. degree in 1950. His work on taxonomical, pathological and biochemical aspects of fruit diseases caused by fungi was excellent. His contributions towards management of diseases during marketing and storage of fruits and vegetables was significant which became highly beneficial to the farmers and dealers, especially in enhancing their shelf-life.

Prof. Tandon began his professional career after appointment as, Lecturer in Botany in 1957, at Allahabad University. His style of teaching with lucid and impeccable English always fascinated undergraduate and postgraduate students. He became Reader in 1970, thereafter Professor in 1982, and Head of the Botany Department in 1983. He had published about 150 research papers in various national and international journals. He was member of different scientific bodies. He had guided more than dozen D.Phil. students. Some of them are holding good positions in University and research institutes.

Prof. Tandon superannuated from service in 1985 but he remained engaged in research, guiding students till last. He was actively associated with National Academy of Sciences, holding high positions, such as, he was Treasurer from 1987-1992, again from 2000-2003 till date, and council member several times. He was also associated with other educational institutions, such as, President of the Managing Committee of Sri Rama Devi Inter College, Allahabad.

Besides academic pursuits, he was keenly interested in social activities. He was President of Lions Club for several years, later became Governor also. He was awarded the Best Citizen Award. He was Director of U.P. Automobile Association, the post which he held till the end.

Prof. Tandon had a dignified personality and always attired meticulously.

Prof. Tandon met an accident at Nainital, later hospitalised in Bareilly and while almost recovering, suffered a heart attack and breathed his last on 15th June, 2003.

He is survived by his wife, four sons, one daughter and grandchildren. His wife could not bear the loss and passed away in August 2003.

His sudden demise has left a great lacunae in scientific and social spheres.

We pray his soul may rest in peace.

Monica Basu

Professor of Botany in Allahabad University, Allahabad

Prof. B. Ramamurthi

Born on 30th January 1922, Prof. B. Ramamurthi, MS, FRCS, D.Sc. (h.c.), FAMS, FNASc, FNA, FASc was a unique combination of a gifted neurosurgeon, a dedicated scientist, a teacher par excellence, an erudite scholar. He graduated from the Madras Medical College in 1943, standing first and winning the coveted Jhonstone Medal. He obtained his M.S. (Surgery) in 1945 and FRCS (Edinburgh) in 1947 in a remarkably short time. He received his training in neurosurgery at the Neurosurgical Service at the Newcastle General Hospital, New Castle, UK and Montreal Neurological Institute, Montreal Canada. Returning to his Alma Mater, he initiated the nucleus of a neurosurgical unit with four beds which he assiduously developed into an internationally renowned Institute of Neurology. Never willing to rest on his laurels, after his superannuation at the young age of 56, he went ahead to establish yet another centre - the Dr. Achanta Lakshmipathi Neurosurgical Centre at Voluntary Health Services (VHS), Chennai.

His scientific contributions covered a wide range of subjects. These included - some seminal works on tuberculosis of the central nervous system, head injuries, cerebrovascular accidents, stereotactic surgery for movement disorders, epilepsy and behaviour disorders among others.

His commitment to excellence and quest to reach the top led him to head some of the most prestigious organizations. He was the founder member and later President of the Neurological Society of India, the National Academy of Medical Sciences, the National Board of Examiners, the Surgeons Association of India and Honorary President of the World Federation of Neurosurgical Societies to name only a few.

He was Fellow of all the three science academics in the country and recipient of John Bruce Gold Medal of the Royal College of Surgeons of Edinburgh, Lord Moynihan lectureship of the Royal College of Surgeons, London, the Dhanwantri award. He was Honorary Surgeon to the President of India and was decorated with Padma Shri and Padma Bhusan. His life's motto could be summarised by one of his favourite quotation from The Man from La Mancha, Don Quixote, "To reach the unreachable star, it is my quest to follow that star, no matter how hopeless, no matter how far".

He is survived by his wife Dr.(Mrs.) Indira Ramamurthi, a distinguished Obstetrician & Gynaecologist and two sons, the elder one a journalist and the younger one a neurosurgeon.

He was elected Fellow of the National Academy of Sciences, India, in 1985.

P.N. Tandon

Meghnad Saha Distinguished Fellow, NASI; and President National Brain Research Centre, Manesar-122050 (Haryana)

Prof. Nitish Kumar Sanyal

Prof. N. K. Sanyal left for his heavenly abode on Oct. 23, 2003. He was well known for his scientific contributions, administrative capabilities and social awareness. Prof. N. K. Sanyal was born on July 6,1933 in a nationalist family of Gorakhpur. His father (Late) Sri Nihar Kumar Sanyal is remembered as a daring lawyer taking a stand favouring the freedom fighters who were accused in the famous Chouri-Choura case. Prof. Sanyal had his schooling in St. Andrews College, Gorakhpur and did his B.Sc. and M.Sc.(Physics) from Allahabad University. He started his research career with Prof. S. R. Palit at Indian Association for Cultivation of Science, Jadavpur. In 1958, he joined Gorakhpur University as Asstt. Professor. Finally he became Head of the Physics Dept. in 1979 and remained so till 1992 when he joined as Chairman, U.P. Higher Education Service Commission. Prof. Sanyal was the founder Vice-Chanceller (1999-2002) of U.P. Rajarshi Tandon Open University at Allahabad. Throughout his career, he was considered as "Institution Builder".

Prof. Sanyal was a Biophysicist and Molecular Physicist of very high order. His work on "light scattering of Hemoglobin" is an important contribution in Biophysics from India. He worked extensively, in molecular force field calculations, biomolecular interactions using quantum mechanical methods, heterocyclic compounds, proteins, polymers, liquid crystals, lipids etc. For his contributions, Prof. Sanyal was elected as Fellow, National Academy of Sciences, India in 1977. He has served on many academic/administrative bodies of various institutions including Motilal Nehru Engg. College (Allahabad), Banaras Hindu Uni-versity, Lucknow University, Assam University, U.P. Board of Technical Education, U.P. State Observatory etc.

In passing away of Prof. Sanyal, the academic community has lost a great teacher, researcher, administrator and above all a remarkable human being. He has left behind his loving wife Mrs. Shima, two children Sanjay and Indrani and a large number of admirers/friends to bemoan his death.

Suresh Chandra

Emeritus, Scientist,
Department of Physics, Banaras Hindu University, Varanasi-221005

Announcement

Prof. H.C. Khare, General Secretary (HQ) of the National Academy of Sciences, India passed away on February 7, 2004 after a brief illness. The Council in its meeting held on February 7, 2004 has nominated Dr. V.P. Kamboj, C-35-A, Fatima Hospital, Mahangar, Lucknow - 226 006 (Phone – 0522-2334378) as the General Secretary (HQ) of the Academy for the remainder duration of late Prof. H.C. Khare's term i.e. uptill December 31, 2004.

Corrigendum

The Academy apologizes for the unfortunate mistake due to which the name of Dr. Amiya Prasad Bhaduri, Dy. Director, Medicinal Chemistry Division, Central Drug Research Institute, Lucknow – 226 001 appeared in the Obituary column in some of the publications of the National Academy of Sciences, India, Allahabad. We deeply regret for the same and pray for the long, happy and healthy life of Dr. Bhaduri.

JOURNAL FORMAT AND GUIDELINES FOR THE AUTHORS/CONTRIBUTORS

[A] WHAT TO SUBMIT

All papers would pass through a strict "Peer review" to ensure high quality.

The National Academy Science Letters publishes articles under the following categories :

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(i) **Prof. Girjesh Govil** (Member, Board of Editors), Formerly Senior Professor, Tata Institute of Fundamental Research, Colaba, Mumbai – 400 005, **E-mail : govil@tifr.res.in;** Fax No. (022) 22804610, 22804611.

(ii) **Prof. Jai Pal Mittal** (Member, Board of Editors), Director, Chemistry and Isotope Group, Bhabha Atomic Research Centre, Trombay, Mumbai – 400 085, E-mail : **mittaljp@magnum.barc.ernet.in**; Fax No. (022) 25505151, 25519613

(iii) **Prof. Suresh Chandra** (Member, Board of Editors) Emeritus Scientist, Department of Physics, Banaras Hindu University, Varanasi – 221 005, E-mail : **schandra@banaras.ernet.in**.; Fax No. (0542) 2317040.

(iv) **Dr. M.S. Sinha**, Executive Secretary, The National Academy of Sciences, India, 5, Lajpatrai Road, Allahabad – 211 002, E-mail : **nasi@sancharnet.in;** Fax No. (0532) 2641183.

(v) **Dr. Niraj Kumar**, Assistant Executive Secretary, The National Academy of Sciences, India, 5, Lajpatrai Road, Allahabad – 211002, E-mail : **nasi@sancharnet.in**; Fax No. (0532) 2641183.

(b) Manuscripts should be typewritten in English, double-spaced and should be submitted in triplicate. All mathematical expressions should be typed or written clearly in black ink. For speedy publication, an electronic version in a "Floopy (3.5", IBM PC format only, not Macintosh)" is desirable. The text of the manuscript as per format of the Journal, and preferably with scanned figures, should be supplied as a plain ASC II file (WordStar 5.5 or 7.0 and Microsoft Word for Windows 6.0 are acceptable, but ASC II is preferred).

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2. Mirri, M.A. (1982) J. Chem. Phys, 58 : 282 (for articles in Journals).
Author Year Journal Vol. I beginning page
White, M.J.D. (1973) Animal Cytology and Evolution, 3rd Ed., Cambridge University Press, London, p. 320 (for Books)
Osgood, C.F. (1977) in Number Theory and Algebra, ed., Zassenhaus, H., Academic Press, New York, p. 321 (for edited Books).
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(e) Keywords : A maximum of 5 keywords should be supplied. Each of these words will be separated by a slash (/) and printed just below the title of the research paper, e.g. (steroid receptors/protein-DNA interaction/gene regulation).

(f) Acknowledgements, if any, should appear at the end of the letter but just before the references.

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